CONTRIBUTIONS TO THE GEOLOGY

OF THE

NORDINGRÅ REGION

BY

JOSÉ M. SOBRAL

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JOSÉ M. SOBRAL

INAUGURAL DISSERTATION

BY PERMISSION OF

THE PHILOSOPHICAL FACULTY OF UPSALA

TO BE PUBLICLY DISCUSSED

IN LECTURE ROOM IV

MAY 26TH, 1913, AT 10 O'CLOCK A. M.

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

ACAD. LUGD. BAT. BIBL.

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Introduction.

The first notices of the rocks and geology of the Nordingrå district were from the pen of AXEL ERDMANN, who in «Kongl. Vetenskaps Academiens Handlingar» for the year 1846 (p. 225) published a paper, «Om de i Sverige förekommande bergarter, som föra hornblende eller angit». He deals with the rocks of the region mentioned in an appendix, p. 271. In «Öfversigt af Vetenskaps Akademiens Förhandlingar» for the year 1847, p. 245, there is a report by ERDMANN on the sandstone formation of Storön. On p. 249 of the same »Öfversigt etc.» appears a communication on «Gångar af granit, genomsättande hypersthenfels». In the year 1848 appears another report by the same author, on p. 11 of the same publication, «Om den titanhaltiga jernmalmen från Ulföarne.»

In «Geologiska Föreningens i Stockholm Förhandlingar» 1874—75, p. 189, appears a communication from C. A. DELLVIK on the iron-ore of Ulfön.

In «Kongl. Svenska Vetenskaps-Akademiens Handlingar» for 1877 Vol. 14, N:o 13, A. E. TÖRNEBOHM published a remarkable paper on the Swedish gabbros and diabases, entitled «Om Sveriges vigtigare Diabas och gabbro arter», and there he referred the Ulfö diabase to the Åsby-type, which he describes in detail.

The most important work published on Nordingrå is that of HJALMAR LUNDBOHM, who is the real discoverer of that interesting region.

In «Geologiska Föreningens Förhandlingar» for 1893, N:o 151, Vol. 15, part 4, p. 231, LUNDBOHM published a preliminary notice, «Om berggrunden i Vesternorrlands kusttrakter».

LUNDBOHM's paper »Berggrunden inom Vesternorrlands Län» appeared in the year 1899, as one of the Swedish Geological Survey's publications, and was a general geological description of that province. He devoted more time to studies in Nordingrå than to other parts of Vesternorrland, and the results were published, together with a detailed map on the scale of 1 : 100000. In this connection it may be stated that the corrections I have made of the map are not of fundamental importance. I have, moreover, worked under more favourable conditions than did LUNDBOHM. There is a great difference between going as a pioneer in the field, with a none

too accurate topographical map, and without preliminary geological knowledge of the region, as LUNDBOHM did, and commencing work with good topographical and geological maps — the latter only needing correction — and with a general description of the country, as in my case. I must, consequently, lay stress on the fact that LUNDBOHM's map and description have been of great help to me during my field studies.

A. G. HÖGBOM visited some parts of the district at about the same time as LUNDBOHM.

In the year 1893, in «Geologiska Föreningens Förhandlingar», Vol. 15, p. 209, appeared a paper by HÖGBOM, «Om postarkäiska eruptiver inom det svensk-finska urberget» where he dealt with the same region.

In «Norrland, Naturbeskrifning», 1906, and in «The Cambrian Geology of Sweden», 1910, he also deals with the Nordingrå district.

In a guide for the International Geological Congress, 1910, «The Igneous Rocks of Ragunda, Alnö, Rödö and Nordingrå», he resumes LUNDBOHM's and his own observations on the geology and petrography of the region in question.

All these works will be referred to from time to time in my treatment of the same subjects.

It is clear that, as Prof. HÖGBOM had personal knowledge of my field of work, his advice was of great value. He has moreover helped me with many critical suggestions, and, as head of the Geological Institution at Upsala, he has done everything in his power to promote my studies and make my task easy. For all this I am under a very great obligation to him.

To Professor HJALMAR SJÖGREN I wish to proffer my very grateful thanks for numerous acts of kindness and for his readiness even to sacrifice his own convenience in order to further my work.

The field-work was accomplished in about eight months, distributed over the years 1909—12. During that time I had occasion to avail myself of the services of many kind and helpful people, to all of whom I am very indebted.

For three months in the summer of 1910 I had the advantage of being accompanied in the field by a schoolboy from Upsala, TH. NEOVIUS; he was always a willing and pleasant companion, and I am glad to have an opportunity of placing on record my estimation of and gratitude for his work that summer.

The maps have been drawn by Miss GERDA JUNGBERG, of Upsala, under my direction. I thank her cordially for her skilful work.

Special thanks are also due to Mr. J. W. NORDWALL of Vattjom for his kindness and helpfulness. Many times he called my attention to rocks which he had observed during his excursions in search of ores, and in many other ways he showed me great friendliness.

The slices were prepared by Mr A. R. ANDERSSON, of Upsala. It is clear that in a work based, at least in part, on microscopical ana-

lysis, the skill of the person who prepares the slices plays an important rôle. I thank Mr. ANDERSSON very cordially for his work in preparing the slices, and for the many services which he was always ready to render just at the right time.

As is to be seen from the paper, there is a great deal of analytical work in connection with the rocks from the Ulfö-region and a lack of it in connection with those from the rest of the district.

My intention was that all the principal rocks should be analysed before the publication of this work, and an analyst promised me to do the analyses. The analyst in question, however, broke faith with me and it became necessary to seek another. For this reason I wrote to the Argentine Consul in Geneva, Mr. MOLINA SALAS, and by his and Professor LOUIS DUPARC's good services I was enabled to secure the collaboration of Professor DUPARC's chief assistant, Mr. MAX WUNDER, who is already at work analysing my rocks.

To these gentlemen I stand very much indebted, and I hope that it will be possible to follow up this paper with another in which light may be shed on some questions by rock analyses. It is specially the rocks of composition intermediate between gabbro and granite which need much of this kind of work. Moreover, I believe that all rocks must be analysed as completely as possible for a more universal comprehension of their nature and relations.

Finally, I wish to express my sincere thanks to Mr. SYDNEY CHARLESTON for his work in reading through the manuscript and making the necessary corrections in it as regards grammatical errors, and also to Miss L. THEGERSTRÖM for patient reading of the proof-sheets.

Geological Synopsis.

The Nordingrå district is about 65 kilometers in length between Hernön, at the outlet of Ångermanelfven, in the south, and Malmön, at the entrance of Örnsköldsviksfjärden, in the north.

Its greatest width is nearly 20 kilometers, between the outer islets to the east from Ulfön and the western limit in the parish of Vibyggerå.

In reality the geologic region in question extends over the parishes of Nora, Nordingrå, Vibyggerå, Nätra and Själevad, but I use the name, *Nordingrå,* suggested by HÖGBOM, because nearly all the rocks are represented within the limits of the parish of this name, and because a short general name is necessary.

The rocks of this district belong to three different geological epochs. A first group, composed exclusively of igneous rocks, is the most important, and is older than the second group, a rather extensive quartzite and sandstone formation, which is considered as Jotnian.

The third group of rocks is younger than the sandstone and consists solely of rocks of igneous origin.

The Sub-Jotnian rocks are anothosites, gabbros, granites and transition forms between these types.

The Jotnian formation is a sediment with a regional character, somewhat variable in composition. Sometimes it is represented by a quite quartzitic rock, but in other cases it is rich in feldspar. It is superimposed upon, and is the continuation of arkoses with local character, which are built up of the constituents of the Sub-Jotnian rocks.

The Post-Jotnian rocks are diabases and monzonites. These rocks intrude and cover the Jotnian sandstone in all occurrences, and it is by this means that the sandstone has been preserved.

Even for non-geologists the difference in the topographical features between this district and the rest of the country is striking.

The Sub-Jotnian rocks are distributed as follows: The granites occupy principally the northern part of the district. They occur in the eastern parts of the parish of Vibyggerå, to the north of Omneſjärden in Nordingrå and in the southern parts of Nätra and Själevad.

The gabbros and anorthosites occupy the greater part of the parish of Nordingrå, the gabbros in the west and south and the anorthosite in the east. There is a long belt of gabbro and monzonitic rocks limiting the granite region to the westward in Vibyggerå. The gabbro occurs on the western coast of Gaviksfjärden in the parish of Nora, and on the south-eastern shore of the above-named firth monzonitic rocks are found. From Bergdalsviken down to the southernmost part of Ramstafjärden occur granitic and monzonitic rocks.

All the Jotnian sandstone occurrences coincide with the Post-Jotnian diabase regions, because the latter has protected the former against denudation. There are, however, cases in which the diabase has been intruded directly into the Sub-Jotnian, so that not all the diabase occurrences are connected with the Jotnian sandstone.

The sandstone and diabase-forming table-mountains appear as a long girdle, stretching along the eastern region of the district, always in a steep slope to the north and the northwest,dipping about 5—7 degrees to the SSE or SE. On the south-eastern side the sandstone is seldom observed; it lies below the surface of the sea or does not exist at all. In these cases the diabase shore is generally accessible. This is well illustrated in the island of Skrubban (NNE from Ulfö). The north and west coasts are for the most part nearly inaccessible, but on the east and south-east coasts it is easy to land.

The formation which, south of the Ramsta bay, borders upon the district on the western side, is a granite, considered to be of Archæan age. This granite also appears in a cape to the north-north-east of Grönviksgrundet. In this region the sandstone lies over the granite and is overlain and intruded by the diabase.

The sandstone of Storön probably lies over the Archæan. South of the village of Grönsvik a stratum of sandstone of the thickness of about two meters appears under the diabase. To the north of the village the sandstone disappears and the diabase shows itself in contact with the granite. The diabase is very fine-grained at the contact.

From Ramsta bay to Norasundet the boundary between the Archæan formation and the rocks of the district passes through a cultivated valley, which is rather narrow north of Allsta but opens out wide at Östanö and Ramsta. It seems that in this region have taken place dislocations, which run along the boundary of both formations.

From Ramsta towards the north, as far as to Nätra, the Archæan formation that borders upon the Nordingrå area consists of leptites.

Ulandsberget, the hill situated north-west of the village of Eden, is about 150 meters in height. On its southern slope (west of Eden) it is covered with great patches of Archæan rocks, and its north-western side is covered by a cap of the same rocks. An analogous phenomenon is to be noticed on the mountain situated north of Gavik — Grönberget. On the

western side of this hill there is a gabbro hillock, isolated by the Archæan formation from the above-mentioned hill.

From Grönberget to Öfver Veda the contact runs in a row of narrow valleys with abrupt and craggy sides, whose bottoms are in general occupied by fens, peat-bogs and small lakes; sometimes the valleys are rather broad and covered with cultivated land and picturesque villages, as in the neighbouring region of Dalberget and that of Salsåker, further to the north.

On Dalberget radial dislocations seem to have taken place. To the east the hill is limited by a precipitous wall, only accessible in a few places. From the top of this hill the geologist can get the best survey over what, from the morphologic point of view, is the most interesting part of the district.

To the north-east are seen the high, granitic hills of Mjällomlandet and Vibyggerå. Towards the south-east, and from the valley below, extends the beautiful gabbro region, with its lakes, its wooded hills and its long and narrow firths; and yet farther in the same direction is seen the long range of table-mountains extending along the coast. This remarkable scenery would, I think, excite the admiration not only of a geologist but of everybody who loves nature.

From Dalberget, straight over the valley, there are patches of Archæan rock covering the gabbro. These appear to be what is left of the cap of old rocks that formerly covered the district.

The most important of these coverings are two: one of them immediately to the north of Mäland, and the other in the hill which lies quite close to Dal on the north-east. Analogous occurrences are observed halfway between Dal and Fröstvik, and in the hills immediately to the west of Färnsvik.

On the northern shore of the Firth of Ullånger, to the east of the little village of Knäppa, there is a hill which demands attention. It is divided into two parts by a little valley, not very deep, through which, in a north-north-easterly direction, passes the contact between the older formation and the Post-Archæan igneous rocks, which in this case consist of gabbro and granite.

The part situated north-west of the valley referred to is of leptite, that to the south-east is of granite, but the top of the latter part is covered by a cap of leptite. To the south-east of the last-named top there is another little hill separated from it by a valley. This hill consists of gabbro, and the contact of the latter with the granite is observed in the above-named valley. The highest part of this hill is also leptite. These coverings of older rocks cannot be considered as big fragments of the Archæan formations, broken by the Sub-Jotnian rocks. They are the remains of a cover of wider extension, which has been isolated by denudation. It seems that the granite dips below the leptite in the higher hill to the north-west.

In some parts of the contact-region — for instance north-east of the little lake of Sätra, as well as in the neighbourhood of Magdbäcken and of Högsvedjeberget — I have seen a kind of eruptive breccias where the fragments were of Archæan rock. North of the northernmost farm of the village of Magdbäcken there is a hill whose base consists of Post-Archæan rock, but whose top part is a cap of Archæan rock. This rock has been strongly metamorphosed by the Sub-Jotnian intrusions, and in some parts a complete melting has taken place.

Between Nylands fäbodar (cow-sheds) and the Lake of Skule the contact region is covered by brushwood and fens. According to LUNDBOHM's map, the region enclosed between Lake Skule and the Firth of Näske (through which flows the rivulet that serves as the outlet of Lake Skule) should be of diabase. But I followed the rivulet along its whole length and, as it was possible to examine many parts of its bed, I could ascertain that it belongs entirely to the Archæan formation. The diabase extends to the south of the rivulet, bordering upon the granitic rocks; but on the northern side I have found diabase only west of Ytterböle and at Näske, on a farm situated by the side of the road to the north of the saw-mill.

To the north of Nylands fäbodar the rocks observed in the contact region are granite and diabase, but never gabbro. These rocks are in contact with leptites the whole way along, in the region of Balhus as well as south of Juviksberget. The same is the case at the southern slope of Igeltjärnsberget between the Firths of Åvike and Guldvik.

An «Ögongneis», which, according to LUNDBOHM, bounds the district on both sides of Bäckfjärden, was not observed by me.

The first things that one becomes aware of, when visiting the district, are the long and narrow firths which extend far inland, and then the relatively high hills, which drop down to the sea in steep slopes and sometimes in nearly vertical walls.

In several cases the firths are continued inland as valleys. The long Sörleviken in Nordingrå is continued inland as a valley, beautiful, long and narrow like the firth itself, to Själand, and there meets it the prolongation of Edsätterfjärden. Färnsvik is continued by a valley in the south-south-west direction as far as Kåltjärn and Omnesjön. Perhaps a continuation of the last-named valley is the line running from Bergsåker, along the east shore of Vågsfjärden and the narrow gorge-like Häggviken.

It seems that there are two principal directions in which the great valleys and firths and, to some extent, the coast-lines run. These directions are, one between N—S and NE—SW, and another nearly NW—SE, perhaps more exactly N60°W—S60°E. I do not mean that each valley and each firth follows these lines without exception, but that these directions predominate in the gabbro and anorthosite regions of the parish of Nordingrå.

I will name some other cases. The coast from the region immediately south of Bönhamn, to the southern part of the outlet of Omnefjärden,

runs in a NNE—SSW direction, and the valleys between Bönhamn and a small lake near the sea-shore NW of Flasen, between N. Mjösjö and S. Mjösjö, from Älgsjö to the region of Näsänget, several narrow dales in the region of Räfsön, a valley from Omnefjärden to the eastern part of Själandsjön, another, the inner part of Omnefjärden, and several valleys in the region of Salsåker and of the boundary between this district and the Archæan — all run in the same direction.

Stretching in nearly a N 60° W—S 60° E. direction are the valleys from Kåsta to Häggviken (south of the village). From Björnås past Gåsnäs runs a valley to Vågsfjärden, and Edsätterfjärden is continued by a valley which goes over Själandsjön, Orstasjön, Lidböle, etc. to Vedasjön. Another valley is the inner part of Omnefjärden over the village of Omne and Omnesjön etc. These long, narrow valleys divide a great part of the parish of Nordingrå into nearly exact parallellograms.

The sea is rather deep in the firths, even quite near land. At Balhusudden, a cape at the entrance of the Firth of Nätra, quite near the shore the depth is between 20 and 56 fathoms and the promontory is 116 meters high at a point even a very short distance inland; and in all the firths to the south the above-named depths are the commonest, and in many cases the hills near the sea attain altitudes of over 200 meters.

It is very probable that the genesis of the firths and valleys and the steep slopes of the hills is, at least in many cases, closely connected with dislocations. In two instances this has been shown to be the fact.

In Omnefjärden, west of a bay called Räflan, at Hamnmyrudden and to the south of this cape is observed quartzite; to the north and east of this cape there is anorthosite, and, some meters higher up, is observed sandstone with its common covering of diabase. [See LUNDBOHM's monograph p. 18.]

Consequently, we find here that, at Hamnmyrudden, the region to the west of the valley connecting the little bay to the east of Hamnmyrudden with S. Räfsöviken has sunk. We find about the same conditions in Trysundaön. There is a dislocation in the western part of Bockviken in a NNE—SSW direction. [The same monograph p. 20.)

I think that the precipitous steep of Dalberget, in the western region of Nordingrå, is formed by a dislocation. Between the top of Dalberget and the bottom of the valley is an altitude-difference of about 300 m.

At Skuleberget in Vibyggerå, on its eastern side, the hill ends in a very steep wall. The top of it lies near the eastern border with an elevation of 293 m.; the seashore is about one kilometer from it, and the valley close to the wall is only a few meters above the sea-level.

Consequently it may be considered that dislocations have had a great influence on the topography of the Nordingrå region.

These dislocations have taken place in different geologic periods. Even to-day earthquakes are often reported from those regions, and that is perhaps the consequence of the above-named kind of tectonic movements. This probably depends upon the uprise of the land, which,

in this region, is the greatest in Scandinavia. It is about 1,5 centimeters per year, according to HÖGBOM.[1]

But it is the circumstances of the consolidation of the magmas and, to some extent, the composition of the rocks that have been of the greatest importance for the land forms.

For instance, the Post-Jotnian diabase has in part consolidated as a covering over the Jotnian sandstone and in part intruded into the Sub-Jotnian and Archæan rocks. Of that intruded in the sandstone the topography is quite typical. It generally forms table-mountains, and the inclination of the diabase surface is generally nearly conformable with that of the sandstone-beds. Of course these land surfaces are not quite plane; there are great irregularities when we come to consider them in detail.

Of this kind of land-forms we have examples in Storön to Omnefjärden in Nordingrå, and in the small islands of Skrubban and Trysunda, to the north of Ulfö. On the contrary, when the same rock does not rest upon sediments, as in the parish of Nätra and in the Archæan regions, the forms do not show the uniformity of the table-lands, but they generally present steep and craggy outlines. The gabbro rocks in Nordingrå build one of the most beautiful of Swedish landscapes. They rise in not very high, but generally abrupt hills. The boldness of their forms, together with the plenitude of lakes, gives to that region an extraordinarily attractive appearance. I believe that in most cases these lakes are due to dislocations. At least the outlines of some of them coincide with the direction of probable dislocations, as has been mentioned above.

The scenery in the granitic regions is generally devoid of beauty, the lines are gentle and the hills more clumpy. They attain greater heights than those of gabbro, but their forms are shapeless.

Lakes are rare in the granitic region, especially in comparison with their occurrence in the gabbro districts. The woods grow better in the gabbro and diabase regions than in those where granite is common; and even the population is greater in the former than in the latter. The greater part of the granitic region in Vibyggerå is nearly uninhabited. The same can be said of the granitic region between Omnefjärden and Ullångerfjärden, in the northern part of the parish of Nordingrå. There is certainly a big village, Mjällom, but this is the only one, if we do not count the fishing village of Norrfällsviken.

All the igneous rocks of this district have several more or less regular systems of joints, which is perhaps more evident in the granites and somewhat less conspicuous in the anorthosites.

Generally it is observed that the system of joints, which is in nearly the same direction as the outer surface, is the most developed, and sometimes the rocks have a bedded appearance. This is specially the case in respect to the granites, but it is not at all uncommon in the diabase and gabbro.

[1] Norrland, Naturbeskrifning. Almqvist & Wiksells tryckeri, Upsala 1906, p. 199.

The above-mentioned system of joints in some of these granites may be developed, so that the distance between two consecutive jointing planes is very slight, making the stone useless for commercial purposes.

What has been said by HÖGBOM on the rocks of Ragunda[1] — that in some granite mountains the quadrangular blocks are quite loose and remain in place because they are in a horizontal position or sloping in such a direction that they support each other — is true over nearly the whole of this district. I think this is a common feature in most granites. Sometimes the blocks are so loose that, by means of hammering, it is possible to move them; and it is a natural circumstance that, such being the case, the weathering must exactly follow the said jointing-planes. The water having an easy passage along these planes, the blocks will become loose, not only through weathering, but also through the action of frost. In this manner quite unaltered blocks may be disintegrated from the rock-mass.

The Jotnian quartzitic-sandstone is divided by very fine joints according to the planes of bedding, but, besides this, by other systems of joints, which give to it a kind of columnar structure. I have not observed any place where it would be possible to get a serviceable block of this sandstone of tolerable size.

This columnar or prismatic structure is well known as being produced by contact with intrusive rocks. Even rather small diabasic dikes can produce such a structure in sandstone. In this case the Jotnian sandstone has been exposed to the influence of thick diabasic intrusions, which probably had a high temperature during a long period, and consequently expansion and contraction have been at their maximum.

Ripple-marks and sun-cracks are very common in this sandstone.

The arkoses have a very well-developed system of joints according to the planes of bedding, which are parallel with those of the sandstone, and there are also systems of joints more or less perpendicular to them.

The rocks of this district are generally relatively little weathered. It is, for me, impossible to explain the fact that sometimes in the same rock-mass, and even in the same hill or mountain, the rock is weathered in some places, but not in others. In some localities this may be explained, as it is by HÖGBOM in the case of the Ragunda region, by the suggestion that in places lying to the south there are greater temperature changes and the rock may decay easier than on the north side. In other cases it happens that the rock on the northern slope of a hill is much weathered, but not on that looking to the south, although the rocks are, at least apparently, the same in composition in both localities.

For instance, at Barstaön the Post-Jotnian olivine-diabase is so decomposed that it is possible to remove it with the help of a spade only; but in the same neighbourhood, for instance in the little islet of Flasen, just to the north of the same island, the same diabase is extraordinarily fresh.

[1] Om Ragundadalens geologi, Sv. Geol. Unders. Ser. C. N:o 182, 1899.

I have observed in many places that the olivine of the diabase, being the mineral which decomposes first, is weathered away, leaving small holes. This is very typical in a weathered surface of that rock. If the olivine crystals are found in reduced proportions in the rock, and, moreover, if they are small, then the rock may resist weathering relatively well.

If the same kind of rock is rich in olivine and tolerably coarse-grained, then the alteration of the olivine may be a sufficient cause for a strong disintegration of the rock-mass.

Perhaps in this way may be explained the conditions referred to as occurring in Barstaön. Similar to the diabase of this island is that of Röåsen near Grönsvik. That name is a consequence of the reddish-brown colour of the weathering products.

Among the Sub-Jotnian rocks that which decays easiest is the gabbro, but in no case does this rock become so decomposed as in the above-mentioned occurrences of Post-Jotnian diabase.

Age of the formations.

The age of the rocks of the Nordingrå district cannot be determined with geological exactitude. It is only by comparisons with other analogous occurrences in Fennoskandia that an approximate result can be obtained. This is so because the first named region is surrounded by formations belonging to the Archæan, and nowhere do their rocks come into contact with younger formations of known age. For this reason I shall give a short account of the geological features of the other occurrences, which may be helpful for the present purpose.

Relations of the Jotnian to the older Pre-Cambrian.

As far as I know, it was first in Finland that attention was called to the peculiarities that distinguish the above-named formations from the Archæan; principally by the publications of SEDERHOLM, followed by those of HÖGBOM, HOLMQUIST, LUNDBOHM etc. in Sweden, and of FROSTERUS, RAMSAY, and others in Finland. In the following account I shall avail myself of the experience of these geologists. Personally I have visited — beyond my own field of work — the Ragunda region, Åland, and the occurrences on Valamo in Lake Ladoga.

Part of the Nordingrå rocks belong, geologically, to the so-called Rapakivirocks. Rapakivi is a petrographic word. It involves a petrographic conception, namely, that the plagioclase in a granite surrounds the orthoclase, generally showing an oval form. This conception is of the same nature as those implied by the terms ophitic texture and eutectic texture. Consequently a rapakivi rock may be found in formations of different ages, and for this reason rapakivi is inappropiate as a geological term. It is only a fortuitous circumstance that in Sweden and Finland these rocks belong to the same geological period. As more suitable I shall use the term Sub-Jotnian in the same sense as HÖGBOM does, signifying by Sub-Jotnian, not the lower part of the Jotnian, but Post-Archæan rocks separated from that formation by a long denudation period.

There is a range of Sub-Jotnian igneous rock-formations from Ladoga in Finland to Jemtland in Sweden. Over the whole region they cut the directions of schistosity of the older ground. They show, however, very few vestiges of dynamo-metamorphism, and hence, as SEDERHOLM [1] has pointed out, we are entitled to presume that the dynamo-metamorphic movements in this ground had finished before the consolidation of the Sub-Jotnian rocks.

The Archæan formations in contact with the Sub-Jotnian occurrences are, in many cases, not only dynamo-metamorphosed, but even palingenetically transformed. This is especially the case in respect to the Swedish and the West-Finnish districts (Ragunda, Nordingrå, Rödö, Åland, Nyland).

In East Finland and in Olónez occur folded Pre-Cambrian sediments, but younger than the specific Archæan. The relations of these formations to the Sub-Jotnian are of great significance for the determination of the limit of the latter formation to the older Archæan. These younger sedimentary formations are the Jatulian and the Onegian;[2] the latter is considered by SEDERHOLM as forming the upper Jatulian. The Onegian rocks are less metamorphosed than the Jatulian, which have generally undergone extensive folding. The dip of the Jatulian strata varies between 30° and 60°, and their strike in south-east Finland is between NNW and NNE. The easternmost Sub-Jotnian district in Finland, that on the northern shore of Ladoga, is intersected by the direction of the Jatulian folding, but the rocks do not show any influence from it. As a consequence of that, the Sub-Jotnian district of Ladoga and, by similitude, the other Sub-Jotnian areas are considered to be younger than the Post-Jatulian and Post-Onegian folding periods.

In several of the districts mentioned there are, in company with the rocks of granitic composition, gabbros and anorthosites that are considered somewhat older than the former.

W. RAMSAY points out (in Geologins Grunder p. 380) that many of these gabbro rocks exhibit signs of pressure and alteration, and for this reason he considers that the corresponding magmas were intruded before the Post-Onegian tectonic movements had quite ceased: and, since they probably originate from the same magma as the Sub-Jotnian granitic rocks and denote the basic phase of an intrusion, the last sequence of which embraces those acid masses, it could be thought that the dislocations that caused the granitic magma's ascensional movements took place under the last part of the Post-Onegian orogenetic period.

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[1] »Atlas öfver Finland». — Über eine archeische Sedimentformation im Südwestlichen Finland. Helsingfors 1899. Bulletin de la Com. Géol. de la Finlande. — Über die Finnländischen Rapakivigesteine. Tscherm. Min. Petr. Mitt. 12, 1891, and other publications.

[2] W. RAMSAY, »Geologins Grunder.» — Beiträge zur Geologie der präkambrischen Bildungen im Governement Olonez, I and II, Fennia 22, 1902. — Über die präkambrischen Systeme im östlischen Teile von Fennoskandia. Centralblatt für Min. etc. 1907, p. 33.

FROSTERUS,[1] who studied the Sub-Jotnian area in the parishes of Jaala, Heinola and Mäntyharju, in Finland, states that the changes which the rocks have undergone are not of much importance.

They are limited (in the gabbro and anorthosite) to a uralitisation of a part of the pyroxene to a secondary biotite from this hornblende and to an alteration in the texture, which is principally observed as a weak deformation of the plagioclase and generally even as a feeble crushing of the quartz grains. All those phenomena, showing that the rock has been exposed to pressure, are, however, generally rare, as FROSTERUS says that it may be doubted whether the rocks have experienced any violent folding movements.

Remarkable, too, says he, is the fact that those phenomena caused by pressure are limited to the more gabbroid, coarse-grained rocks, while the diabasic types hardly show signs of metamorphism, their textures being quite primary.

As a consequence of my experience with exactly similar rocks, I believe that the gabbroid rocks are not more dynamo-metamorphosed than the granites.

With respect to the alteration of the pyroxene, in uralite, it may be stated that this phenomenon is not necessarily a consequence of dynamo-metamorphism.

The Ulfö-diabase, for instance, is a quite unaltered rock, and there it is not possible to find the least sign of dynamo-metamorphism, for its geology and its petrographical features show clearly that this rock has not been exposed to pressure.

There are dikes cutting the Ulfö-diabase (and consequently of less age), the pyroxene of which is partially and in some cases totally transformed into uralite.

RAMSAY's statement concerning the differences of age between the basic gabbroid rocks and those of granitic composition is thus open to discussion.

That the anorthositic and gabbroid rocks consolidated before the granites is quite certain, but this need not necessarily imply that the granites were intruded much later than the gabbros. It is possible that they were contemporaneously in the fluid state, filling the cavity where we now find them. The final stage in the consolidation, that which we see now, where the granites intrude the gabbros intimately in the form of dikes, does not signify that the gabbros were intruded much earlier. The gabbro will necessarily have consolidated before the acid granitic rocks. I believe that the granites have undergone the same dynamo-metamorphosis as the gabbros, and that this has been very feeble. I have very often found the quartz of the granites showing evident signs of pressure, and many others have made the same observation.

[1] Beskrifning till Bergartskartan S:t Michel, Helsingfors 1902.

HOLMQUIST, in his monograph «Om Rödöområdets Rapakivi och Gångbergsarter», p. 13, says that the Rödö granite sometimes shows very evident signs that the rock has undergone pressure. But, in comparison with that to which the Archæan rocks have been subjected, this influence is very slight.

We start from the idea that the gabbro magma has been intruded before the Post-Onegian folding period quite ended and that the intrusion of the acid granitic magma followed afterwards.

These magmas have consolidated at a certain depth below a covering of older rocks. The depth differed for different districts.

After their crystallisation followed a more or less long period of denudation, during which the covering was removed.

When the rocks came to the surface began a period of disintegration. After this time there was built an arkose, which in some places in Nordingrå reaches a thickness of more than 20 meters, and over the arkose was deposited the Jotnian sandstone.

It may be pointed out that the arkose has been found only in Nordingrå; we must, however, take into consideration that some of the Sub-Jotnian districts in Finland are largely covered with younger deposits, and, as far as I know, the contact between the Jotnian sandstone and the subjacent rocks has not been observed. Consequently it is not certain that this arkose is to be found only in Nordingrå.

In Hogland (Finland) there is a sedimentary formation, deposited over the Archæan, and, covering it, a quartz-porphyry. The latter is considered to be contemporaneous with the Sub-Jotnian rocks.

The sedimentary formation is a quarzitic conglomerate and it is quite unfolded.

RAMSAY, in his description of the geologic map of «Hogland and Tyvärsaari», states that the conglomerate is composed of pebbles of light gray quartzite, between 2 cm. and 20 cm. in diameter, kept together by a quartzitic cement. Sometimes are observed pebbles of granite and gneiss, but never of quartz-porphyry. They have the original rounded, somewhat flattened form, and show no traces of dynamo-metamorphism.

These conglomerate beds, lying at the same level and over the higher regions of the mountains, seem to have belonged to horizontal strata that now dip very slightly to the east.

The unchanged form of the pebbles and the unconformity of the conglomerate resting upon the upraised and denuded gneiss-strata do not permit of these formations being considered as belonging to the Archæan, but they must be Post-Archæan.

The same author, in his textbook «Geologins Grunder» 1909, p. 380, considers that the quartzite-conglomerate in question is possibly of the Jatulian age.

SEDERHOLM, in «Atlas öfver Finland» and in «Les Roches prequaternaires de la Fennoscandia», remarks that the quartzite sandstones and

conglomerates of Hogland may be considered as constituting the oldest part of the Jotnian or Sub-Jotnian formations, but it seems to me that these geologists are somewhat inconsistent in these questions.

They have adopted dynamo-metamorphism as a kind of measurer of the age of the rocks, while, on the other hand, it has been considered that all these formations older than the sparagmite and devoid of dynamo-metamorphic signs must be considered as belonging to the Jotnian (see, for instance, SEDERHOLM: «Explanatory Notes to accompany a Geological Sketch-map of Fenno-Scandia», 1908).

Then it is singular how the conglomerate of Hogland and the slightly folded Almesåkra series or the same conglomerate and the considerably folded Jatulian formations can be considered to be of the same geological age.

It seems to me difficult to understand how RAMSAY, who considers that the Sub-Jotnian gabbros have been dynamo-metamorphosed by the Post-Onegian folding movements, can at the same time express the opinion that the conglomerate of Hogland, devoid of the least traces of dynamo-metamorphism, possibly belongs to the Jatulian.

If the quartz-porphyry of Hogland is contemporaneous with the Sub-Jotnian granites, then the conglomerate can not be Sub-Jotnian, and much less Jotnian; it must be of Post-Onegian age at least; and if the said conglomerate is Jotnian, then the quartz-porphyry is younger than the granites alluded to; it must be Post-Jotnian.

If we do not accept the foregoing statements, it is necessary to admit that the adoption of dynamo-metamorphism to measure the age of the formations is not trustworthy. I hope that I shall not be misunderstood by geologists outside Fenno-Scandia; the dynamo-metamorphical signs, which in other countries have very little signification for the mentioned determinations may, in Fenno-Scandia, outside the Scandinavian Highlands, be applied with discernment, because, after the Jatulian period, the orogenic phenomena diminish in intensity, and, after the Jotnian, there are no traces of folding.

Consequently it may be stated that the dynamo-metamorphic signs in the Sub-Jotnian rocks are very feeble and that they are of the same intensity in the gabbros as in the granites. The relations of the Nordingrå-rocks to the Archæan may be considered as fairly clear, in the light of the results obtained by the Finnish geologists in south-east Finland and Olónez — this as a consequence of the great analogy in geological and petrographic features between them and the Finnish Sub-Jotnian occurrences.

Relations to the Cambrian.

Nowhere is it possible to find contacts between the Jotnian and the Cambrian, for which reason there has not been any certainty in respect to their relations, and till recent years the assertion as to the Pre-Cambrian age of so-called Jotnian formations was grounded on indications which lead one to suspect it without fully proving it.

It is very possible that the Jotnian sandstones and quartzites had a very large extension, and that, after a long period of denudation at the beginning of the deposition of the Cambrian sediments, they were almost completely denuded.

Their relics are preserved by dislocations, or by diabase beds, which are probably of Pre-Cambrian age.

There are many occurrences of sandstone and quartzite which are considered to be Jotnian, because of their geological and petrographical characters.

HÖGBOM has very properly compared them with the Torridonian in Scotland and the Keweenawan in the northern states of U. S. in regard to their relations to the Cambrian and Archæan and the manner in which they occur.

The sedimentary formations which are grouped under the Jotnian, are scattered over an extensive region in Fennoscandia, but it is seldom that a single occurrence attains any considerable extension. The Dala-sandstone is the most considerable of all the Jotnian areas, and extends over the NW region of the province of Dalarne.[1]

The other Swedish occurrences are in Gefle and Ångermanland, and there are some of less extension in Upland.

In Finland they are found at Björneborg, Isojoki and Kauhajoki, and, besides this, on the eastern shore of Lake Onega, and probably on the bottom of Lake Ladoga below the diabase beds of Walamo.

The Post-Jotnian diabases are typical for the occurrences of Jotnian sandstone. They have been observed in their company as beds, or as dikes, or as somewhat large intrusions in the Pre-Jotnian regions, but never intruded in a Cambrian or Silurian formation.

TÖRNEBOHM and HÖGBOM consider it as probable that the Dala-sandstone is older than the sparagmite-formation (a Pre-Cambrian formation of the Highlands) but there are no indisputable proofs of this.

There have been some attempts to demonstrate the Pre-Cambrian age of the Sub-Jotnian rocks independently of the relations of the Jotnian sandstone to the Cambrian.

[1] A. E. TÖRNEBOHM, Grunddragen af det Centrala Skandinaviens Bergbyggnad. Stockholm 1896. See also, ALFRED ELIS TÖRNEBOHM, Minnesteckning af A. G. HÖGBOM, Geol. Fören. Förhandl. Jan. 1912.

During a part of the summer of 1894, J. G. ANDERSSON[1] was engaged in geological studies in Gotska Sandö, where he found two blocks of Cambrian conglomerate. In both blocks were found pebbles of a red-coloured igneous rock, the biggest of which had a length of 12 mm. In one of the blocks occurred numerous small, often fragmentary and worn specimens of Torellella lævigata. The pebbles of the red-coloured igneous rock were all small and generally very altered. From the 13 pebbles were selected four of the less decomposed.

Their examination showed that they consisted almost entirely of quartz and orthoclase in graphic implication. The quartz did not show any signs of pressure, and for this reason it was considered with certainty that the rock from which the pebbles originated must be included among the Post-Archæan igneous rocks.

«In any case it is quite certain», thinks ANDERSSON, »that Post-Archæan igneous rocks, petrographically identical with a part of the rapakivi-series from Åland, form part of a Baltic Cambrian conglomerate, as denudation-remains.» «Here», concludes ANDERSSON, «is a new proof gained for the Pre-Cambrian age of the rapakivi-rocks».

That the graphic texture should be considered as a means of deciding whether a rock belongs to the rapakivi-series or, more properly, to the Sub-Jotnian rocks, or not, is, in my opinion, not right.

The graphic texture is certainly not common among the igneous rocks older than the Sub-Jotnian, and it may be thought that rocks violently dynamo-metamorphosed and re-crystallised may lose their original textures, which in many cases may have been of a graphic or eutectic nature. But among the younger Archæan igneous rocks there are several examples of the texture named. HÖGBOM mentions[2] that in the Skellefteå district there are quartz-porphyries with micrographic texture.

The same author speaks of a medium- to coarse-grained, red-coloured granite, occupying a large surface of the country in the neighbourhood of Jörn. This granite also shows the texture referred to. The commonest feldspar is micro-perthite. The femic minerals, biotite and magnetite, are found in subordinate amounts and fill the intermediate spaces between the salic constituents. HÖGBOM even states that this rock recalls the Sub-Jotnian granites, but that it is somewhat more pressed.

The conglomerate which is to be found to the west of Jörn contains pebbles of this rock. The conglomerate is penetrated by bosses of Ser-Archæan granite and is probably of Bottnian age. Thus, Jörn-granite must be considered as probably being Pre-Bottnian.

There are similar granites in Arvidsjaur. The pebbles in the conglomerates between Kusfors and Wargforsen, to the north of the Skellefteå river, originate from the same kind of rocks.

[1] Till frågan om the baltiska postarkäiska eruptivens ålder. Geol. För. i Stockholm Förh. Bd 18, 1896, p. 58.

[2] Pre-cambrian Geology of Sweden. Bull. of the Geol. Inst. of Upsala. Vol. X.

A red-coloured, graphophyric granite composes several hills in the vicinity of Hemberget and Siksjö.

All these granites are older than the Ser-Achæan granites. The Rätan-granite, which extends from the northern region of Orsa Finnmark to the southern bay of Storsjön, in Jemtland, is counted among the Ser-Archæan granites. This granite, according to TÖRNEBOHM, is distinguished by its miarolitic and micrographic texture. It is red-coloured, porphyritic and titanite-bearing in a very high degree, and does not show signs of having undergone pressure. Even in the Upsala region it is possible to find micrographic textures at the boundaries between the hälleflinta and the Upsala-granite.

Consequently, it may be stated that graphic texture is not a quality or sign of separation between the Sub-Jotnian and the older granites.

The other argument employed by ANDERSSON to prove that the conglomerate-pebbles originated from Sub-Jotnian rocks was the absence of signs of pressure in the quartz. In some granite-bodies which belong to the younger Archæan there may be regions in which the typical phenomena, indicating the effect of dynamo-metamorphism, are absent, and it is specially in the border zones that the consequences of pressure are quite evident.

I have studied slices of some granitic rocks from the Skellefteå district, and there are no notable pressure phenomena in the quartz. However, these rocks are much older than the Sub-Jotnian.

Besides this, there may be still unknown granitic regions older than the Sub-Jotnian, but younger than the Archæan proper, from which, at least locally, the signs of pressure are absent.

I consider, consequently, that ANDERSSON's observations do not prove that the «rapakivi-rocks» are Pre-Cambrian, but they are an indication that it may be so.

These observations have, however, a great value, because the assemblage of several indications which point in the same direction may constitute evidence, or a real proof. HÖGBOM's discovery of pebbles from a diabase of the Åsby-type in a Cambrian bottom-conglomerate at Locknesjön, in Jemtland, is, in my opinion, of greater importance, because all the known occurrences of Åsby-diabase are younger than the Jotnian quartzites and sandstones, and possibly two denudations and a deposition-period separate the mentioned diabases from the Sub-Jotnian rocks. I have had an opportunity of seeing slices of these pebbles: they were altered, but show the typical petrographic features of the Åsby-diabase-type.

The Finnish geologist, V. TANNER, has demonstrated the Pre-Cambrian age of the Sub-Jotnian rocks in Åland.[1]

[1] Über eine Gangformation von Fossilienführendem Sandstein auf der Halbinsel Långbergsöda—Öjen im Kirchspiel Saltvik, Åland—Inseln. Helsingfors, Mai 1911. Bull. de la Commission Géologique de Finlande.

About 25 years ago ROOS found dikes of sandstone in the granites of Åland, and SEDERHOLM and FROSTERUS made similar finds during the field-work for the geological map of Finström, but they never found fossils in them.

It was GAVELIN's[1] discovery of sandstone-dikes with fossils, south of Åmål, that induced new field-studies of the sandstone-dikes in Åland.

TANNER studied eight sandstone-dikes occurring in the rapakivi-granite in the north-eastern part of the parish of Saltvik, by Långbergsöda. The dike that TANNER calls N:r 3 is the most interesting, because it contains fossils.

C. WIMAN, who studied the fossils, expressed the opinion that they were Cambrian brachyopods recalling Kutorgina or Acrotreta.

Accordingly, the arguments for the Pre-Cambrian age of the «rapakivi-rocks» are:

1. Pebbles of a diabase of the Åsby-type have been observed, forming part of a Cambrian conglomerate.

2. Pebbles of a red-coloured granite, with graphic texture and without traces of dynamo-metamorphism, have been found in blocks of a Cambrian conglomerate.

3. Dykes of Cambrian sandstone have been found in the rapakivi-granite from Åland.

[1] Om underkambriska sandstensgångar vid västra stranden af Vänern. Sveriges Geologiska Undersökning. Ser. C. N:o 217.

Storön.

The southernmost part of the Nordingrå district is Storön. It has a length of about 4 km. and in its greatest breadth is a little more than 1 km. Nearly the whole island consists of Post-Jotnian diabase. It is only in its south-western region that another rock occurs, where the Jotnian quartzitic sandstone formation appears, building an abrupt shore. The lower part of the Jotnian is below the sea. These sediments are quartzitic sandstone and slates. The diabase lies over them. In the most southerly cape of the island, Brattbergsudden, the sandstone is intruded by numerous dikes and veins of diabase, especially at the contact with the diabase covering. The intrusion of the dikes and veins has taken place along the planes of stratification.

At Brattbergsudden the quartzitic sandstone has a width of 30 m. and a thickness, above sea-level, of 8 m. At a place some meters north-east of Brattbergsudden the quartzite has a thickness, above the sea, of 14 m. There are probably many small dislocations, causing differences in the observed heights of the upper layers of the sedimentary formation. In a cape north of Brattbergsudden, where the coast line runs to the north-east, the width of the Jotnian is 66 m. and the thickness, above the sea, 21 m. Immediately to the south of the fishermen's huts this formation attains a thickness of 3,5 m. and a width of 12 m. The dip of the layers is variable in magnitude and direction. At one place it was 4° to the south-east, and in another locality in the neighbourhood 6° to N 80° E.

The small inclined plain where the fishermen have built their huts also seems to consist of Jotnian rocks. North of it the diabase reaches the sea, but 75 m. to the north the quartzite appears again. The dip there is 6° to S 80° E, the breadth 8 m. and the thickness 3,50 m. The width of the sediments diminishes towards the north, becoming wider at the bay SW of the lake. The lake has been a strait dividing Storön in two, but the rising of the land converted it into a bay with an entrance from the east, and at a later period the same phenomenon enclosed the basin completely.

The Jotnian occurs on the southern and south-western shores of the lake. The hill to the south-west of the lake consists, in its lower parts, of

sandstone, and its upper part is a diabase calotte. Between this and the other hill, 250 m. to the north-east, there is a region of sandstone. It is very probable that the Jotnian also occurs on the bottom of the lake. On the south-western slope of the first-named hill the dip is about 6° to the east, the width of the sandstone 54 m., and the contact with the overlying diabase is at 7 m. above the sea. The height of the hill is about 40 m, so that the thickness of the diabase covering is about 33 m. At about 400 m. to the north-east of the second hill the Jotnian disappears. It is probable that the Jotnian sediments are here deposited over Archæan rocks. Ripple marks and sun-cracks are common. It will be observed in the map that the sandstone regions have, in many cases, a greater width than that given in the description. This is because the sediments would not appear in the chart if represented in their true proportions, while it is important to show their mode of occurrence to explain the geological conditions. The measurements were taken with a measuring-tape and the greater heights calculated by means of barometrical observations.

The quartzitic sandstone consists principally of *quartz* and very turbid *feldspar fragments;* as accessory constituents appear *mica, magnetite* and *kaolinite.*

The *feldspar* is pigmented. It is this pigmentation that gives their reddish colour to the Jotnian sediments. The feldspars are nearly undeterminable as a consequence of their turbidity, but they are probably in all cases orthoclase, and some crystals I could determine were of this mineral. They very often included many small magnetite grains; kaolinite and muscovite was observed attached to them. The feldspar grains are generally somewhat rounded, but appear also in fragmentary and irregular forms. In most cases their section does not exceed 0,20 mm.[2]

The *quartz* grains are rounded and irregular in form, and are always less than 0,50 mm[2] in section. They come directly into contact with each other in some cases, and in other cases are held together by a ferruginous cementing material, which is perhaps of a hematitic nature, but it plays a subordinate rôle. Sometimes there is an argillaceous cement found also. This cementing matrix, however, plays an insignificant rôle in the rock, and it may be said that the quartz grains are generally in contact with each other. There occur accumulations of *kaolinite* and *muscovite. Biotite* appears very sparingly in small and irregular flakes. *Magnetite* occurs in part as inclusions in orthoclase and in part as more independent grains, distributed in the rock-mass. This rock is decimillimeter-grained.[1]

The clay-slates, which occur in layers of no great thickness, are very fine-grained and consist principally of *mica, hematite* and *quartz.* These clay-slates are connected by transition forms with the quartzitic sandstone, and consist of alternate layers of quartziferous material and of ferruginous material relatively poor in quartz. The *mica* seems to be muscovite. The

[1] I use IDDING's terminology. See Igneous Rocks. Vol. I. New York. 1909.

largest mica flakes attain dimensions of (0,003 × 0,001) mm.^{2}, but are generally much smaller. It is, moreover, very difficult to distinguish the different crystals, because they occur together in accumulations of minute flakes. I am not able to say with certainty what their position is in relation to the planes of sedimentation, but I received the impression that they are not parallel to it.

The *hematite* occurs in rounded particles, also in lamellar crystals and in clusters of very minute grains. The clusters are elongated in the sense of the stratification, and the lamellar crystals are also parallel to the same direction.

The *quartz* occurs in rounded, sometimes elongated and lenticular crystals, but also with angular outlines. When elongated they have the longitudinal direction parallel to the strata. In most of the quartziferous regions the quantity of iron minerals decreases and pigmented orthoclase appears. The above-mentioned layers of quartzitic material contain very much muscovite, which mineral occurs perhaps in nearly the same amount as the quartz.

The slate, then, consists of alternating layers of different composition. They are principally of two kinds: those rich in iron minerals and relatively poor in quartz, and those poor in hematite and rich in quartz, muscovite occurring in both cases in great amount. The relation between the thickness of the ferruginous layers and that of the quartziferous is as 4 to 1. At 200 m. to the north of Brattbergsudden the sandstone is traversed by a diabase-dike in a direction according to the planes of bedding. The diabase-dike has a thickness of about 1 m. and is crossed by a vein of a reddish rock with a thickness of 5 cm. I could not decide with certainty if this vein cut the sandstone or not, because it was not possible to see a limit between them, and unfortunately I was not able to take a specimen of the contact for microscopical examination. It was a vertical wall, and only below the contact, by an irregularity in the rock, could I secure a sample of the vein. The vein-rock was full of small irregularly-shaped miarolitic cavities containing calcite.

The essential minerals of the rock are *albite* and *quartz*, and the accessory *apatite, calcite, garnet* and *chlorite*.

The albite is the mineral that gives the reddish colour to the rock. This colour is caused in the albite by the interposition of very small rods of a mineral which I could not determine. The rods are generally parallel to the same direction in each crystal.

The quartz and the albite occur, for the most part, in graphic implication.

The rock is decimillimeter-grained. It is a rock of an aplitic character, belonging to a group of dike-rocks of varying composition, which will be described later in the chapter on Ulfön. The Post-Jotnian diabase will also be described in detail in that chapter.

The Ramsta area.

The region south and east of Ramstafjärden is occupied principally by the Post-Jotnian diabase. In the neighbourhood of the firths of Ramsta and Grönsvik the Post-Jotnian rocks intrude and lie over the quartzitic sandstone, forming table-mountains. The Sub-Jotnian rocks of the district occur between Bergdalsviken and the southernmost part of Ramstafjärden, and are covered by the quartzitic sandstone. Fig. 1.

From the fishermen's huts in Bergdalsviken, in a SSW direction, the ground is covered with sandstone pieces and loose blocks, right up to the diabase escarpment. At a short distance to the west of the place in question the sandstone is visible between the heights of 20 and 38 m. above the sea. Between 38 and 58 m. the ground is covered with diabase blocks. Above the latter height the diabase occurs as a covering. The probable width of the sandstone belt is between 80 and 90 m. This profile was taken about 100 m. westward of the huts. At cape α there is a zone of about 23 m. in width occupied by a granitic rock. Over that comes an arkose, which probably has a width of nearly 110 m., attaining a thickness of 20 m. The contact between this rock and the Jotnian sandstone is hidden by younger deposits. At a height of about 63 m., and 250 m. from the shore, the ground is covered by diabase-blocks, and at 350 m. from the shore the diabase is found *in situ*. Continuing to the south, one comes to the highest point of the table-mountain, about 148 m., and the whole way the diabase forms the ground. The thickness of the sandstone here is probably nearly 65 m. and the diabase calotte somewhat more, perhaps 70 m. Going from the little bay, which lies about 600 m. south of cape β, to the east, one finds the same granite as is observed by the shore, extending to a distance of 90 m. and an altitude of 16 m. The ground then becomes covered with woods and younger deposits. At a distance of 180 m., and 22 m. above the sea, appears a fen. At a distance of 250 m. and a height of about 30 m. the arkose can be seen. Nearly 300 m. from the shore, and at 40 m. above the sea, there is a conglomerate, consisting principally of quartz pebbles, which some-

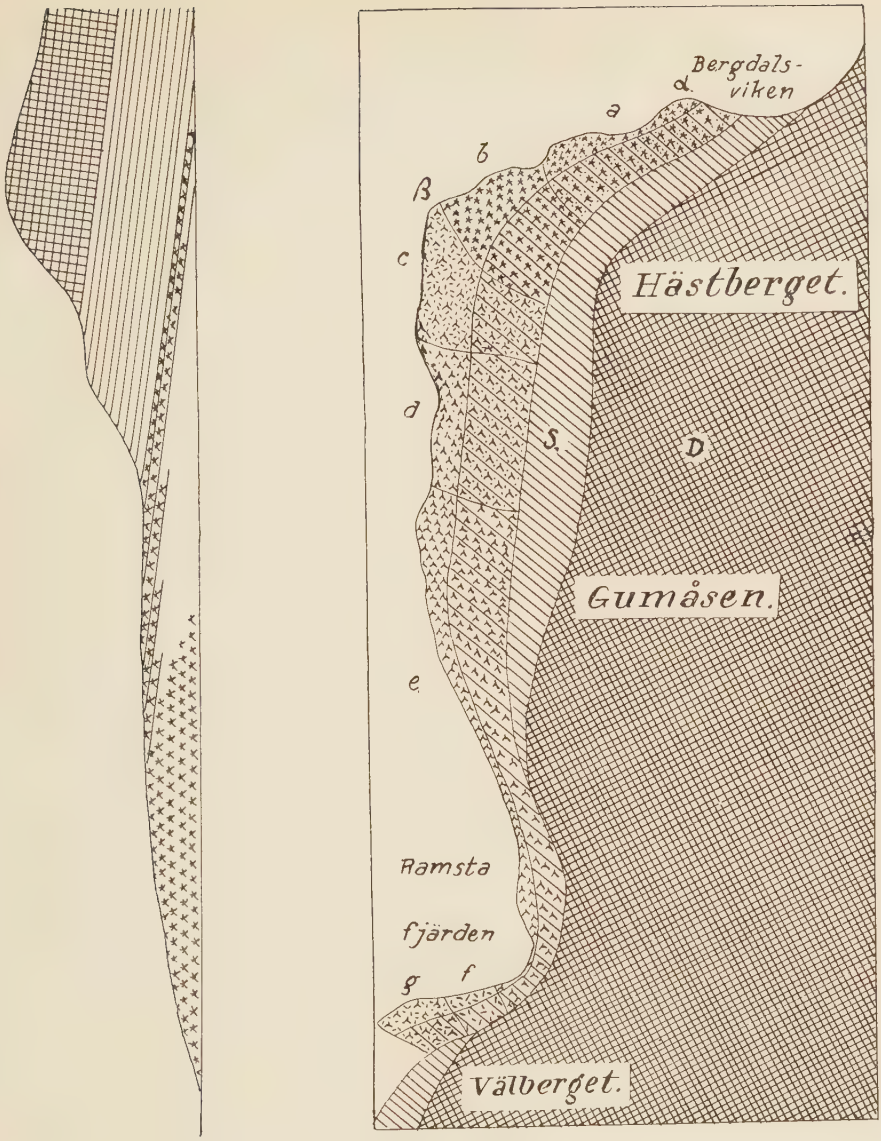

Fig. 1.

Sketch-map of the eastern region of Ramstafjärden on the scale of 1 : 25000 and profile over Hästberget taken from cape β in a south-easterly direction. The direction N—S is marked by the lines of the cross-ruled part of the sketch-map which make the most acute angle with its length. The cross-ruled region, marked with a D, represents the Post-Jotnian rocks. The region designated by an S corresponds to the quartzitic sandstone (Jotnian). The small regions a, b, c. d, e, f and g, are occupied by the Sub-Jotnian rocks, and the region between them and the sandstone by their corresponding arkoses. In the regions a and b the rocks are pyroxene bearing granites. The rocks of the region c are of a constitution very like those of the acid representatives of the monzonite series. The region d is occupied by biotite-granites, which are connected by transition forms with the rocks of c. In the region e occur very fine-grained biotite and muscovite granites. In f and g the rocks may be considered as varieties of those occurring in c.

times attain a diameter of 7 cm. The pebbles are cemented together by a quartzitic sandstone. This conglomerate lies directly over the arkose.

The probable width of the sandstone belt is about 190 m., but the contact with the diabase could not be observed. The dip is about 7° to the SE. All the way to a place south-east from the southernmost islet in Ramstafjärden I found the same relations between the Jotnian sandstone and the arkose, their basement of igneous rocks, and the covering of diabase. In that place the diabase is observed at a height of about 50 m. and it seems that there is no sandstone there. At an altitude of 10 m. the arkose was noted.

From this locality to the south the igneous rocks are observed along the shore line, but inland, to the east, the ground is covered the whole way to a steep diabase escarpment. At Välberget, on the southern part of Ramstafjärden, we have quite the same relations between the different rock-groups. On the northern slope the lower part of the sandstone is at a height of 40 m. above the sea, the upper at about 90 m.; and the highest part of the diabase covering at a height of 185 m. The thickness of the arkoses in this locality is about the same as in the north-eastern region of the firth. It is very difficult to state an approximate figure for that thickness, because the igneous rocks go over into these arkoses and are connected by means of transition rocks. If we could see a vertical section, then it would be possible to determine the limits approximately, but the section is in a very sharply inclined plane, and just in the limit region the rocks are generally hidden. I believe that the arkoses generally exceed 20 m. in thickness. On the western slope of Välberget the upper limit of the sandstone is at 100 m., and the lower at about 70 m. The width is about 120 m. In the southern region of Välberget I did not observe the sandstone, but it reappears in the north-western slope of Röåsen. The upper contact of the sandstone is at a height of 100 m., and the lower probably at 75 m. The breadth is 75 m.

The *a*-region.

In the region *a* the rocks are pyroxene-bearing and of varying composition. In most cases they are of granitic constitution.

The *feldspars* are orthoclase and plagioclase, but in varying proportions. There are varieties of this rock with very limited quantities of orthoclase, and then they have a more pronounced grey colour. On the contrary those varieties with more orthoclase have a reddish colour, as a consequence of the pigmentation of this mineral, but I believe that in part the reddish colour is the result of the alteration and pigmentation of the plagioclase.

The *orthoclase* is usually so turbid as to render difficult its determination.

The *plagioclases* are generally the most important constituents of the rocks. They are commonly somewhat altered, and in some cases their decomposition has proceeded very far, so that only some reduced portions of the crystals are in the primary condition.

All the crystals compared have an index of refraction higher than that of Canada balsam and lower than ε of quartz. But the determinations made on (010) give as a result that some crystals have an extinction angle of 0°, and others one of between 6° and 7°. Some other crystals show a feeble zonal structure; with an extinction on (010) of 6° in the central parts and nearly 0° in the peripheric regions. In the zone at right angles to (010), I have measured extinction angles up to 22°,3. Then they may be considered as oligoclase-andesines and andesines, between Ab_{70} An_{30} and Ab_{60} An_{40}. The largest section of plagioclase observed is (3,75×1,65) mm.^{2} There are many approaching that figure, besides all sizes between it and (0,30×0.15) mm.^{2}

The plagioclase crystals are generally anhedral, though exceptionally they show some crystallographic faces. In most cases they approach the equant form. They are twinned according to albite, pericline and Carlsbad.

Quartz. After the plagioclase the quartz is generally the mineral that occurs in greatest amount. It occurs in anhedral crystals. The crystals may be as large as the plagioclases. Sometimes it is observed that it has outlines characteristic of those minerals that have crystallised last, and then it contains inclusions of plagioclase; in other places in the same slice we see it in graphic implication with plagioclase, both minerals showing a quite irregular cross-section; and in other regions of the same slice it has more independent outlines, showing a rounded configuration.

Graphic implication is very uncommon — it may be said that it occurs only exceptionally. But it is observed that apparently different quartz crystals have the same orientation, being separated by several other crystals of different minerals. This is probably due to very irregular quartz individuals, which shoot out ramifications; the other minerals being, at least in part, included by them. That may be considered a special case of the poikilitic fabric, the matrix having too slight an extension. Somewhat analogous is the case in some basic rocks; the augite, being the last mineral to separate, occurs in relatively large flakes separated from each other and with the same orientation, the other minerals with different orientation filling the intervals. If these flakes were united together we should have a poikilitic texture. Irregularly-shaped inclusions are very common in the quartz of this rock, and some of them are fluid.

Biotite. — This mineral occurs in part in isolated crystals of about 1 mm^2. in section and in part in aggregations of smaller and variously

oriented crystals. The crystals are generally flattened according to (001) and are quite anhedral. It is poikilitic, the inclusions being of all the other minerals.

The pleochroism is Z = Y = dark brown > X = pure yellow.

The optic angle is very small, but observable.

Hypersthene. It is only in small crystals that this mineral occurs, and, as it is for the most part altered, it is conceivable that its determination may be difficult. It is altered to bastite and uralite. The pyroxene has separated before the quartz, feldspars and mica, but is seldom observed presenting a crystal face of any sort, commonly occurring in anhedral, small and rounded crystals, which in most cases have a diameter of about 0,40 mm.

Magnetite occurs in very small crystals and has crystallised before the orthorhombic pyroxene. The dimensions of the biggest sections are about (0,40×0,30) mm.^{2}, but generally they are below that measure. A great part of the magnetite occurs as inclusions in the mica, and then the crystals show very reduced dimensions. The biotite generally contains magnetite crystals in large amounts.

Apatite is observed in great quantities. It has been the first mineral to separate and appears in prismatic crystals. Their dimensions vary, but are always small. They may be in a section perpendicular to the c-axis about 0,06 mm. in diameter, and the same crystal may be 4 or 5 times as long in the direction of the same axis, but the relations between the length and width may vary very much, and occasionally the crystals are very long and needle-like.

The texture of this rock, which is phanerocrystalline, does not recall the granites of the Ulfö-type. An idea of the granularity may be got by considering the dimensions of the different minerals above treated. It is a millimeter-grained or a medium-grained rock.

The fabric is seriate homeoid. This rock shows no more signs of dynamo-metamorphism than the other Sub-Jotnian rocks. But this is the only property common to the granites of the Ulfö-type. An attribute which is very typical of the last-named type, the graphic fabric, occurs very seldom in this rock, and then it is a very local and limited phenomenon. The mineral composition varies very much, and the same may be said of the chemical composition.

This is, moreover, a type of rock which, as far as I know, has not been described from the other Sub-Jotnian districts.

In the western region of Bergdalsviken, and west of the cape that limits that bay in the direction named, cutting the above-described rock, occurs an aplitic dike-rock, the minerals of which are *micro-perthite, albite, quartz, biotite, muscovite,* and some *apatite.* It is a reddish, medium-grained rock, with much quartz, and the primary femic mineral, biotite, occurs in limited amounts.

Micro-perthite is the commonest constituent. It occurs in relatively large crystals of sections of about (2,50×1,00) mm.^{2} The albite traverses

the orthoclase in irregular layers. These layers are sometimes lenticular. In the lenses I have observed some zonality. The central parts show an extinction angle of 16°, but the extinction of the periphery is 19°,5 on (010). The perthite crystals are pigmented very irregularly; in the same crystal there are regions quite clear and others very turbid.

Plagioclase. — There are independent crystals of plagioclase, which seem to have separated before the other minerals. This plagioclase appears to be albite, or at least a plagioclase with a composition approaching that of albite. In some cases it shows about the same index of refraction as Canada balsam, but generally the index is lower. In the symmetrical zone the maximum extinction angle observed is about 16°. Observations by other methods are rendered difficult by the very marked alteration. Sometimes it is observed that very turbid, nearly opaque crystals are surrounded by a wreath-like mantle of quite clear plagioclase, with the same composition and orientation as that of the kernel, of which it is the continuation, the only difference being the turbidity. The area of the sections of the plagioclases are in the mean about $(1{,}05 \times 0{,}38)$ mm.^{2}

Quartz occurs in great amounts in this rock and is commonly anhedral, attaining about the same dimensions as the micro-perthite.

Biotite. — This is the only dark mineral in the rock and occurs in limited quantities. It is commonly altered to chlorite and hematite. The colours are Z = Y = green > X = yellow. The crystals are very anhedral and sometimes occur in accumulations together with muscovite. Sometimes it is difficult to discern if we have to deal with a big, altered crystal, or an accumulation of several small grains. The sections of such accumulations may be $(4{,}00 \times 2{,}00)$ mm.^{2}

Muscovite is more common than biotite, but it is evidently a secondary mineral. There are observed fan-shaped crystals of this mineral, which continue inwards within a perthitic crystal, in the shape of a network of muscovite. It occurs in groups or accumulations of many individuals in contact with each other, and in small flakes distributed throughout the whole rock.

Apatite is observed specially as small inclusions in the biotite. In some cases it attains greater dimensions, as for instance $(0{,}70 \times 0{,}40)$ mm.^{2} in section. In this rock the apatite crystals are generally anhedral, but they seem to be the first mineral separated.

As may be understood from the given dimensions of the crystals, this rock is phanerocrystalline and the fabric is equigranular, the feldspars, quartz and mica, which give character to the texture, being of the same order of magnitude.

In the region west of cape α the rocks, as has been said before, vary in appearance and composition. In one of these varieties — with somewhat more orthoclase than in the hypersthene-bearing rock described above — are observed reddish veins, about 1 cm. in width.

These veins consist of *micro-perthite, plagioclase,* and *quartz,* and originally there has been some *biotite,* the last-named being the sole

femic mineral. The dark mica has been almost completely altered. Chloritic products are observed even in the feldspars. In some chloritic accumulations occurs hematite. Between the cleavage laminæ of the decomposed mica appear lenticular depositions of carbonates.

The feldspars are about the same as in the above-described muscovite-bearing rock. The albite in the perthite is not in well-determined bands or layers crossing the orthoclase, but occurs more intimately implicated. The relations between the feldspars and quartz are also nearly the same. The quartz in many cases shows very marked undulation, though surrounded by other quartz crystals almost devoid of it. As a general rule the quartz of this vein shows incomparably greater undulation than that of the country-rock.

There is a tendency to the graphic fabric, and local developments of graphic texture have been observed between perthite and quartz, as well as between albite and quartz.

Although there is not a well-determined division plane between the vein and the country-rock, the whole looking as if the minerals of both rocks tooth together, the vein has a more fine-grained texture at the contacts than in the centre, and in the centre is rather coarse-grained — coarser than the country rock itself.

The fine-grained zones extend to about 3 mm. on each side, the coarser central region being 4 mm. There are perthite sections from the last-named part of the vein of the length of 5,20 mm. and of the width of 2,00 mm. The quartz crystals do not occur with such great dimensions, but sections of (3,00×2,00) mm.^{2} are not uncommon. At the contact the quartz crystals are about 0,70 mm. in diameter, but they may be smaller. The feldspars show nearly the same measurements. It may be stated that the coarse-grained zone does not follow the centre of the vein always, but in some places it comes nearer to the contact.

This rock is probably a secretion of the magma that solidified as country-rock, and the mode of occurrence, as well as the composition, is aplitic, and presumably it is contemporaneous with the muscovite-bearing dike-rock mentioned above.

The *b*-region.

In the region *b* there is a grey-coloured rock of granitic composition. I am not able to decide the age relations between it and the above-mentioned hypersthene-granite, but I consider the rocks to be contemporaneous. The composition is very similar and the geologic relations quite analogous. The contacts between them are of such a nature that nothing about their relative age can be deduced.

The rock consists of *plagioclase, quartz, biotite, hypersthene, magnetite* and *apatite* and, besides these, of other minerals of secondary origin. Perhaps there is some *orthoclase,* but I have not detected it. The index

of refraction of the plagioclases is always higher than that of Canada balsam. Many determinations of the extinction angles on (010) flakes give values between 6° and 7°. The highest extinction in the zone at right angles to (010) was 19°. In sections perpendicular to X the extinction was 19° and on (001), 2°. — All these values determine the plagioclase as an andesine between Ab_{60} An_{40} and Ab_{62} An_{38}. They are partially altered to kaolinite in confused aggregations. When unaltered they are white, without any pigmentation. Twinning according to albite is the commonest, but also twinning according to pericline and Carlsbad occurs.

The dimensions of the feldspar sections are, in the mean, $(2{,}50 \times 1{,}50)$ mm.^{2}, but in some cases they attain $(5{,}00 \times 2{,}00)$ mm.^{2}

Biotite. — The colour is Z = Y = dark reddish-brown > X = pure yellow. Twinning is common. The dimensions of the mica sections are generally large, attaining 4 mm^2, but in the average they range between 2 and 3 mm^2. They commonly contain many inclusions of feldspar, quartz, magnetite and apatite, pleochroic halos appearing around the included minerals. After the plagioclase and quartz, biotite is the most common mineral. Sometimes the mica not only includes small feldspars, but in its neigbourhood there are accumulations of the same untwinned feldspars, which are quite like those in the leptite inclusions. I consider it as very probable that they come from the leptite fragments, which are very common in this region.

Hypersthene. — That this mineral is hypersthene is shown by the parallel extinction in vertical sections, by the fact that the negative acute bisectrix is normal to (100) and that the obtuse bisectrix appears perpendicular to a basal face (001). The pleochroism is feeble. The colour is yellowish with a greenish tinge; sometimes it appears to be yellowish-white. This is probably a variety not rich in iron, which is also shown by the optic angle, which is relatively large. The sign of the mineral is negative, and the dispersion very weak $\rho > \upsilon$. In basal sections the hypersthene appears sometimes subhedral; (100), (110) and (010) sometimes appear well developed. A section parallel to (001) has a mean length of 0,240 mm. and a width of 0,180 mm. In a vertical direction the same crystals may measure 0,38 mm. The hypersthene separated before the plagioclase, quartz, and mica.

It has altered to bastite and hornblende, but there occurs also a mineral resembling actinolite attached to these decomposition products. The pleochroism is feeble in white, yellow and green shades. Sometimes it shows biotitic inclusions. It occurs commonly in lamellar masses. Very often the extinction is not homogeneous, so that in this respect they resemble fan-shaped minerals, or those in which the twinning lamellæ are much superposed.

Magnetite occurs for the most part in small crystals, as inclusions in the biotite. It crystallised before the above-mentioned minerals.

Apatite appears in very small crystals, and was the first mineral to separate.

This rock is millimeter-grained and the fabric is almost equigranular, taking into consideration only the mineral which plays the greatest rôle in the texture.

This hypersthene-biotite-granite is quite analogous to the above-described from the western region of Bergdalsviken, and they are connected by means of intermediate forms, the only difference lying in the quantity of orthoclase. This rock is crossed by dikes of about 10 cm. in width. The dike-rock is grey-coloured and fine-grained. This dike-rock consists of *orthoclase, micro-perthite, quartz, albite, biotite* and, as accessory mineral, *apatite*. The minerals are named in quantitative order. They have generally about the same magnitude, excepting the biotite and apatite. The perthite crystals are somewhat larger and the quartz grains somewhat smaller. The area of the perthite sections is about 0,45 mm^2, and the quartz sometimes attains these dimensions.

The biotite occurs in anhedral crystals, flattened according to the cleavage plane. It is altered to chlorite. The pleochroism is as follows: Z = Y = very dark green > X = brownish-yellow. The dimensions of the sections are about (0,45×0.15) $mm.^2$ This rock is then decimillimeter-grained and may be classified among the aplites. The relations between the different minerals in respect to the degree of euhedrality is complicated; it seems, however, that none of the essential minerals have better crystal outlines than the others. The rock has the texture that ROSENBUSCH calls »panidiomorph-körnig». Just at the margin of the dike the rock is almost without biotite, and there is some graphic texture locally developed. This margin-zone is about 2 mm. broad, and macroscopically nearly white.

The c-region.

The grey hypersthene-biotite-granite of the *b*-region is an almost homogeneous rock, contrasting in this quality with the rocks from the *c*-region. The rocks of *c* are always reddish in very varying shades.

Near the contact with the grey granite appear two rocks of nearly the same qualitative composition. Macroscopically the contact between them appears very sharp, but when we study it in slices it is not very distinct. On the side of the coarser rock there is a contact-zone almost devoid of the dark minerals mica and hornblende.

In both rocks the commonest mineral is *micro-perthite,* after that come *quartz, hornblende, plagioclase,* some *biotite, apatite, magnetite* and *zircon.* Biotite and plagioclace occur in greater amount in the coarser variety.

In the more fine-grained rock the quartz often occurs in grains attaining 0,70 mm. in diameter; the perthite individuals are sometimes larger, but not much. Both minerals may, however, appear in very small grains. The hornblende crystals attain, in the mean, (1×0,30) $mm.^2$ but in most cases they are

somewhat smaller, the plagioclases (0,70. × 0,20) mm². Consequently it is decimillimeter-grained. In the coarse variety the perthite attains 4,00 mm². The quartz is sometimes as large; the plagioclase (1,00 × 0,75) mm². The hornblende attains 2,00 mm². The rock, then, is millimeter-grained.

The plagioclase is generally somewhat zonally built; sometimes it is turbid in the central parts of the crystals, but the peripherical regions are quite clear. The maximum extinction angle in the zone at right angles to (010) was 15°. The extinction angle in a section at right angles to the bisectrix X was found to be about 9°. On (010) the extinction is generally 0°. Consequently they are oligoclase-andesine and oligoclase. The plagioclase seems to have crystallised before the perthite and quartz.

The *micro-perthite* individuals are generally unaltered and have oligoclase-andesine and quartz crystals as inclusions. Sometimes they are implicated with quartz. This perthite is built of irregular layers of albite traversing the orthoclase.

The *quartz* crystals are of quite irregular shapes.

The *amphibole* is a common hornblende. Pleochroism is strong; Z somewhat darker than Y, Y = dark green, X = brownish-yellow. It occurs, in most cases, as irregular crystals, but sometimes it is subhedral. I have reasons to suppose that the hornblende is not primary in this rock. In other, more basic varieties of this rock there occurs a monoclinic pyroxene, and it seems that the amphibole of these rocks, which is the same as in this case, is of secondary origin. Besides that, I have observed that the kernels of some crystals of hornblende do not consist of the same mineral as the periphery, but of a fibrous aggregate of hornblende with somewhat different double refringence, which may be considered as an earlier stage of the transformation from pyroxene to hornblende. It may be mentioned that in the kernel there occur some accumulations of a reddish-brown pigment. I have also observed in the more fine-grained variety that some kernels were partially filled with calcite, together with some chlorite and magnetite, which would support the contrary supposition — that it is an alteration of the amphibole, which has begun along fissures and afterwards spread to the interior.

Biotite occurs in very small amounts. *Magnetite, pyrite, apatite, zircon* and *fluorite* have been observed; apatite and zircon in well-faced crystals; magnetite sometimes in euhedral, but for the most part in subhedral and anhedral crystals. The relations between these rocks and the grey granite of the region *b* are not clear, but it appears that they are of about the same age. The grey granite loses its grey colour and becomes reddish at the contact.

Quite near the rocks described at cape β, about 100 m. to the west of the contact with the grey granite, occur pyroxene-bearing varieties. The pyroxene is very altered to hornblende and only the kernels of the crystals retain their primary characteristics. It is a monoclinic pyr-

oxene and very probably an augite. On (001), the axis shows strong dispersion $\rho > \upsilon$. The colour is yellowish-white and does not show pleochroism. The angle of the optic axis seems to be the usual one, and the sign is positive. In the region *c* the rocks always occur with very varying compositions, all the forms studied being rocks rich in quartz. I imagine that these rocks belong, for the most part, to the adamellite division of the monzonite series; the most basic of them perhaps approach the banatites.

There are *aplite* dikes cutting these rocks. The aplite is of a red colour and consists of orthoclase, perthite, albite, quartz, hornblende and biotite.

The minerals generally show sections of about 0,50 mm^2, but in some cases they reach nearly 1 mm^2. The orthoclase, microperthite, albite and quartz generally show almost the same degree of euhedrality. Perhaps the plagioclase and quartz show somewhat more independent outlines. The feldspars are generally turbid, especially the orthoclase.

The *biotite* occurs in small amounts and in irregular crystals of small dimensions. The absorption formula is Z = Y = very dark green > X = dark yellow. Sometimes this mineral is very altered.

The *hornblende* also appears in very limited quantities and in anhedral crystals. The pleochroism is just the same as in the amphibole of the country rock.

This rock is decimillimeter-grained and the fabric is seriate homeoid. It occurs in narrow dikes, generally only a few centimeters in width.

In the region *c*, at about 400 m. SW of β, I noticed a dike of Post-Jotnian diabase. We can observe in this dike a «metastable zone». The plagioclase and olivine phenocrysts have separated in larger and more numerous crystals, in a zone of 3 or 4 mm. in width along the contact wall. The probable explanation of this phenomenon, with a detailed description of it, is given in the chapter on the basic dikes of the Ulfö-diabase.

The *d*-Region.

The hornblende and pyroxene rocks of the region *c* show progressively less and less of these minerals, the biotite replacing them. At some meters to the south of the above-mentioned diabase-dike there are only biotite granites. In the region *d* the ground consists of those biotite granites. All these rocks are medium-grained and have almost the same mineral composition. The differences between them are almost only a matter of colour. They are grey, reddish-grey, and reddish-coloured in many shades.

It happens, it is true, that two of the granitic rocks show a sharp contact with each other, but the only important difference between them is the granularity, this dissimilarity, however, not being great. None of them show a chilled contact zone, consequently it is very probable that they belong to the same magma and have been intruded nearly at the same time.

I shall describe one of these rocks as an example, typical of all the other varieties. The first biotite-granite in the neighbourhood of the limit between *c* and *d* is a grey rock with some pink shades. It consists prinpally of *micro-perthite, plagioclase, quartz* and *biotite*. The accessory minerals are: *zircon, apatite* and *magnetite*.

The *micro-perthite* is the most common constituent, occurring in anhedral, unaltered crystals, with sectional dimensions of between 1 and 2 mm^2. There occur, however, crystals of larger dimensions, between 4 and 5 mm^2. The albite of the microperthite is generally turbid and traverses the orthoclase in irregular bands.

The *quartz* generally occurs as anhedral crystals of about 1 mm^2. and shows somewhat more independent outlines than the perthite. The latter very often includes quartz-grains. These two minerals never occur implicated.

The *plagioclase* is turbid through alteration and difficult to determine with certainty; it appears, however, that it has a composition near that of albite. In some flakes parallel to (010) I have found extinction angles approaching 20°. The sections of this mineral are, in the mean, below 1 mm^2. and sometimes show some euhedrality. It has separated earlier than the above-mentioned minerals, at least in part, because it is included by them in many cases. The proportions in which the plagioclase appears are about the same as those of the quartz. Sometimes is observed some zonality in the plagioclases. The central parts are generally very altered to kaolinite and muskovite.

Biotite is the sole dark mineral occurring in the rock. It appears in irregular flakes, showing sections between 0,50 and 1,00 $mm.^2$ in the mean. The pleochroism is Z = Y = very dark brown and X = yellow. Inclusions of quartz and plagioclase are common.

Apatite is sometimes observed in relatively great amount. *Magnetite* and *zircon* occur in small quantities. This granite is a millimeter-grained rock of seriate homeoid fabric. As a general remark about the granites in the region *d*, it may be said that in some varieties a graphic implication between microperthite and quartz is developed locally. The plagioclases are, at least in part, altered, the central being the most altered parts of the crystals. The alteration-products are kaolinite and muscovite. The biotite is in some cases decomposed. It has been transformed into a green variety. Hornblende has not been observed, excepting in the transition forms at the limit with the region *c*.

The *e*-region.

In the region *e*, on the coast of Ramstafjärden, the ground consists of fine-grained granitic rocks. These rocks are greyish and reddish in colour, and have the same mineralogical composition. Indeed, I think that a

chemical investigation of their quantitative composition would show that they are very similar.

They can be divided, according to their granularity, into decimillimeter- and micron-grained rocks. They occur in sharp contact with each other, but sometimes streaks of the coarser-grained are observed in the other.

The mineral constitution is as follows: *orthoclase, plagioclase, quartz, biotite, muscovite.*

The *orthoclase* contains inclusions of plagioclase and quartz, but never occurs implicated with these minerals. It seems to be one of the minerals last crystallised and occurs as regularly in granitic rocks. It has been partially altered to muscovite. The angle of the optic axes seems to be nearly 0°.

The *plagioclase* is an albite, generally very turbid and altered to kaolinite and muscovite. It has crystallised before the orthoclase, but generally occurs in anhedral crystals.

The *quartz* appears in very irregular grains and in many cases shows less euhedrality than the orthoclase.

The *biotite* occurs in irregular crystals and is altered to a green variety. It is the only dark mineral excepting *magnetite,* which only appears in very slight amount.

Muscovite is of secondary origin, being an alteration-product of the feldspars. It sometimes occurs in relatively large, but irregular crystals, and in other cases as a network, covering rather large areas, over several orthoclase and albite crystals.

The magnitude of the minerals is suggested by the statement that the rocks are decimillimeter- and micron-grained. Its variations, however, are not so slight, especially in the coarser rock; the minerals attain an area of 1 mm^2.

In the micron-grained rock the fabric is equigranular, and in the decimillimeter-grained rock the fabric is seriate homeoid.

The *f*-region.

In the region *f* there occurs a variety of granite which is very altered. The only original minerals are orthoclase and quartz. The plagioclases are entirely decomposed; of mica and hornblende there are not the least traces. Secondary accumulations of magnetite and other alteration-products are common. This is perhaps only a variety of the rock which occurs in the region g, but I have separated them because they are now, and seem to have been originally, somewhat different. The greater part of the alteration-minerals of this rock are kaolinite, muscovite and magnetite.

The *g*-region.

The rock observed in this region is a reddish variety, very like those of the region *c*. It consists of *perthite, plagioclase, quartz, hornblende* and *biotite*. This last mineral is in very small amounts. Pyroxene I did not observe. Besides that occur *apatite, magnetite* and *zircon,* as accessory constituents.

The *perthite* appears in crystals of about 1 mm^2. in section, coloured by a red pigment. Locally it is implicated with quartz. Sometimes it occurs surrounding the plagioclases.

The *plagioclases* occur in crystals of the same dimensions as the perthite, but there are cases in which their sections attain dimensions of more than 3 mm^2. In sections parallel to (010) they show an extinction angle of 0°, being then oligoclase-andesines Ab_{69} An_{31}. They are altered, for the most part to kaolinite. This makes their determination difficult. They generally show more regular shapes than the perthite and seem to have separated before it.

Quartz is observed in crystals of smaller dimensions than the feldspars, but in many cases they attain magnitudes approaching those of plagioclase and perthite. This mineral seems to have been the last to crystallise, but has in part separated contemporaneously with the perthite.

Hornblende appears in anhedral crystals. The pleochroism is Z = dark brownish-green > Y = dark brown > X = yellow. The angle of the optic axis seems to be smaller than in common hornblende.

The magnitude of the crystals is very variable; their sections attain up to 2 mm^2., but generally they have smaller dimensions.

Biotite occurs in small quantities, and is the same as that described from the rock in the region *c*.

In well-shaped crystals appear *apatite* and *zircon,* as inclusions in the foregoing minerals; *magnetite* occurs in small, irregular grains, and seems in several instances to be a secondary product originating from the decomposition of hornblende, together with chlorite and carbonates.

The crystallinity, granularity and fabric are nearly the same as in the rock from the region *c*.

Very often it is observed that this rock (region *g*) is crossed by pegmatitic veins. These are sometimes sharply limited from the country-rock, but in other cases there is not a well-defined contact. The veins are sometimes ramifications from small badly-defined dikes. They are generally short, and one gets the impression that their intrusion took place before the complete crystallisation of the country-rock.

The graphic fabric can sometimes be observed with the unaided eye, but a great part of the rock has a micrographic texture, the two extreme forms of granularity being bounded by transitions.

The pegmatite consists for the most part of micro-perthite and quartz in implication, but there is some plagioclase, hornblende and magnetite

in small quantities. Here and there appear accumulations of small, ragged hornblende crystals, the spaces between them being occupied by micropegmatite, isolated quartz crystals with different orientation occurring occasionally.

In the slices studied have been observed regions of 66 mm^2. with a uniform orientation in the implication. The magnitude of the different quartz-grains is variable within wide limits in a single implicated individual. It ranges from those with a diameter of 0,01 mm. to those with a sectional area of 0,09 mm^2. This in the fine implication. In the coarser implication the quartz sections attain about 2,00 mm^2.

As accessory minerals occur *zircon* and *magnetite*, the latter in thin needles, sometimes with a length of more than a hundred times the width. The magnetite has crystallised first; its long needles traverse the graphic implication in all directions. The mean length of the crystals is 0,52 mm., but in some cases it reaches over 1,00 mm.

In one instance I observed a crystal with the characteristic quadrille structure of microcline. The section was such that a determination of the optical properties of the mineral was not possible.

Pegmatitic veins and dikes of this kind are rare in this district.

The Archæan (?) Granite of Ramsta.

The rock which limits the district to the west, in the southern part of Ramstafjärden, is a grey medium-grained granite, considered by LUNDBOHM to be of Archæan age.

This rock consists of *plagioclase, quartz, hornblende* and *mica*, and besides that, as accessory constituents, *apatite* and *magnetite*.

The *plagioclases* are zonally built, the kernels showing an extinction angle, on (010) faces, of 0°, and in the peripherical regions of the crystals an extinction angle up to about + 8°. Hence the composition ranges between $Ab_{69}\ An_{31}$ and $Ab_{80}\ An_{20}$. In all the sections compared the index of refraction was higher than that of Canada balsam.

The plagioclases show tolerably large dimensions, there having been found, in several cases, sections with a surface of 7 mm^2. The feldspars being the minerals which play the most important rôle in the texture of the rock, it shows a rather coarse texture. The plagioclase is the mineral that occurs in greatest amount. It is somewhat altered, especially the kernels. In general it may he said that this mineral has a tendency to subhedrality, occurring in square sections with tolerably regular outlines.

Quartz comes next to the plagioclase in quantity. The crystals of this mineral are of much smaller dimensions than those of the feldspars;

their sections rarely exceed 1,00 mm^2. They are always anhedral and sometimes occur with rounded shapes.

Biotite. The pleochroism is Z = Y = dark brown > X = yellow. Occurs in accumulations of many crystals with different orientation, together with hornblende, sometimes implicated with it, and in isolated irregular crystals, of relatively large dimensions in many cases. It is not uncommon to find sections attaining 2,00 and 3,00 mm^2.

Hornblende. This is a common hornblende, without strong pleochroism. Z = green (not dark) > Y = brownish-green > X = yellow. The axial angle is large. Twinning is common, the twinning plane being parallel to (100). Between the two large twinned parts occur lamellæ in twinned position. The mean area of the hornblende sections is 0,45 mm^2. Occurs in somewhat less quantity than the biotite.

The rock is millimeter-grained and the fabric seriate homeoid. This rock appears the whole way from Ramstafjärden to the southern region of Grönsviksfjärden. In some places — for instance in the southernmost promontory of the east coast of the firth, near the contact with the Post-Jotnian diabase — it shows very evident traces of dynamo-metamorphism. The undulosity of the quartz is very marked. To the south-south-east of the village of Grönsvik there is another locality where the same granite occurs. In the slices examined there is not more undulosity in the quartz than in the same mineral occurring in the youngest rocks of the district.

These marked signs of dynamo-metamorphism are probably quite local, and are perhaps due to the neighbourhood of some dislocation.

For these reasons I consider it difficult to find a cause sufficiently convincing for a sharp age-separation between this granite and the other rocks of the district.

LUNDBOHM[1] states that at the foot of Espsäterberget there is red «gabbro-granite» of the same kind as that of Ramsta — with a fragment of the hornblende-granite that occurs to the west of Grönsvik.

By «red gabbro-granite» LUNDBOHM means the rock of the region *g*, and he designates by Espsäterberget the mountain which, with the natives, I call Välberget.

According to these observations the relative age of these rocks may be considered as determined. From their contact features I could not decide the age relations, because I never observed a sharp contact, and I never saw dikes of the one crossing the other; and I believe these are the certain criteria for such determinations.

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[1] Prakt. Geol. Und. inom Vesternorrlands län II, 1899. S. G. U. pag. 16.

The Arkoses.

From the region of Bergdalsviken to the south-western part of Ramstafjärden the Sub-Jotnian rocks are found — as has been pointed out — only at the sea level and a little above it. On getting higher one finds that the rocks become more and more altered, and at an altitude of some meters below the bottom of the quartzitic sandstone we get extraordinarily decomposed rocks, whose origin can be ascertained, because we can follow all the transitions between them and the unaltered igneous rocks some meters below.

LUNDBOHM has not come to any settled and definite opinion about the relations between the above-characterized igneous rocks and the formations lying over them. But among the explanations put forth by him in his monograph we find the right one, or at least an indication of it.

He states[1] that, from the southern region of Ramstafjärden to Bergdalsviken, the lower parts of the table-mountains consist of a variegated mixture of different granites and gabbroid rocks, and in them occur included portions and fragments which in their outward appearance resemble helleflintgneis,[2] but which could also be supposed to be slates from the overlying sandstone formation. LUNDBOHM could not determine whether they were the one or the other.

He says, moreover, when describing Ringkalleberget, that at Dörnestaudden, and at the coast northward from this cape, the rock is a fine- to medium-grained dark green, diabase-like gabbro, and that the same rock with somewhat changed appearance is observed at a distance from the sea-shore, and on a somewhat higher level. It is covered here by a strange rock with varying appearance, sometimes schistose, in other cases devoid of schistosity and showing numerous porphyritic crystals of reddish feldspar in a grey-black groundmass. The direction of the schistosity nearly conforms to that of the overlying sandstone beds.

He continues that, with the help of the microscope, it can be seen that the rock is much altered, and in some slices are observed more or less evident signs of pressure.

The thickness of this rock, which may be considered to be a very altered gabbro, has not been measured, but is estimated at ten meters at least.

I have cited LUNDBOHM's opinion on the arkose in the western region of Ringkalleberget, because, in this case, his interpretation of the geological circumstances is in contradiction to that of the conditions in Ramstafjärden, referred to above.

The supposition that the fragments included in the granites of Ramstafjärden could be slates from the overlying sandstone formation has,

[1] Prakt. Geol. Undersökn. inom Vesternorrlands Län II. S. G. U. 1899, p. 16.

[2] Leptite.

as corollary, the supposition that the granites referred to must be younger than the Jotnian quartzitic sandstone formation, but this is impossible for two reasons:

1:o. The gabbros and anorthosites of the district are intimately crossed by granitic dikes and veins. The same is the case even with the granites — they are cut by aplites.

The anorthosites are, moreover, crossed by gabbro-dikes. The leptites are also crossed by dikes from the named rocks. Consequently we must consider that the granitic and gabbroid magmas of this district — at least in many cases if not in all — were not so viscous as to prevent the penetration of the older rocks. Especially the granites were, in some cases, probably very fluid. There are many examples where they have intruded the gabbros and anorthosites in very narrow and, in some instances, almost microscopic veins, besides in very thick dikes. Knowing this, we must conclude that, if the quartzitic sandstone formation were older than the rocks in question, it would be traversed by dikes from their magmas; but that has not happened. The Jotnian sandstone formation is penetrated only by the olivine-diabase and the rocks attached to it.

2:o. Everywhere the sandstone lies over an arkose-like rock. The latter is united by transitions to the underlying, unaltered igneous rocks.

Besides this, I believe that there can be not the least doubt that the fragments observed in the rocks of Ramstafjärden are leptites. Of course they are metamorphosed, but they are recognizable.

It must be mentioned that HÖGBOM[1] interpreted the relations between the Sub-Jotnian and the Jotnian in the right way, when he expressed the opinion that in this district the Jotnian lies over arkoses.

The Western region of Ramstafjärden.

The rocks of the two small islets in Ramstafjärden, Granen and Örnen, are of the same constitution as those in the region *d*. In the southernmost part of Västra Allstaholmen occurs the same kind of rocks as in *c*. Its northern part, as well as Västra Allstaholmsgrundet and Östra Allstaholmen, consists of gabbro of the same kind as that found in the parish of Nordingrå. The gabbro contains numerous fragments of leptite and is crossed by granitic dikes.

In the neighbourhood of the village of Ramsta the rock is about the same as in the region *c*, of the east coast, and *g*, of the southern part of Ramstafjärden. It contains fragmentary inclusions of a fine-grained, reddish granitic rock with big hornblende crystals.

In some cases there is a fine-grained central part in the inclusions, surrounded by a region of the same rock, but with big hornblende crystals.

These inclusions consist of *perthite, albite, quartz, hornblende, magnetite, titanite* and *apatite*.

[1] Precambrian Geology of Sweden 1910.

The *amphibole* is a common hornblende with Z = dark green > Y = brownish-green > X = clear brownish-yellow. It occurs in big crystals, the sections attaining a magnitude of 6,00 mm². The amphibole crystals are generally poikilitic and contain inclusions of perthite, quartz, magnetite, albite and apatite. The dimensions of the hornblende grains are sometimes very small, and then it happens that they present crystallographic shapes and are without inclusions.

Albite occurs, in part, forming perthite, and, in part, as independent crystals, some of which attain dimensions of 5,00 and 6,00 mm². These large albite crystals are tabularly flattened parallel to (010). They are, however, not common and are in most cases of lesser dimensions.

Micro-perthite occurs for the most part in small grains less than 1,00 mm². The orthoclasic parts of the crystals are red-pigmented, in some cases very strongly so.

Quartz appears in some cases filling the spaces between the other minerals and also implicated with perthite. It happens that numerous, small grains of plagioclase lie imbedded in quartz, showing a kind of poikilitic inclusion phenomenon. It occurs that many quartz-grains, separated by the other minerals, show the same orientation over large areas, suggesting the possibility that they form part of a single, big and very irregular crystal.

Titanite. There occurs a pleochroic mineral, with colours ranging from yellow to brown, with very strong birefringence and high refringence, in very irregular crystals, whose optical properties, excepting those named, I could not determine because of lack of suitable sections. I am inclined to think it is titanite.

Apatite and *magnetite* appear in small crystals included in the other minerals. The latter appears to be titaniferous, because some crystals are surrounded by leucoxen.

Zircon is also present in small, well-shaped crystals.

In these inclusions there are portions composed almost entirely of micro-perthite and quartz, which are, in part, implicated. Besides these, calcite and magnetite are present.

Like the rock of the region *c*, on the east coast of Ramstafjärden, this is crossed by aplitic dikes of a reddish colour. Their composition and relations are identical with those of the *c* region.

In the hill to the north of the village of Ramsta occur dikes of a reddish-grey, granitic rock, with dark stripes. It seems to be identical with the fine-grained rocks described from the region *e*, on the east coast of the Firth of Ramsta. The dark bands — which give the impression of streaks — have the same composition as the rest of the rock; the only difference being in the granularity. In the streaks the grain is much finer.

In the hill on whose south-western slope lies the village of Allsta there is a small granitic region quite close to the village. On the way up the hill from the valley below, after the bounding line of the Archæan

is passed, there appears a region of big leptitic fragments; then, at some distance higher up, there is a porphyritic gabbro, crossed by dikes of a grey granitic rock; afterwards appear numerous leptitic fragments again; and finally the granite is observed, some meters higher up. Leptitic fragments occur again at higher levels, and they cover a great part of the hill-top.

The granite is grey, sometimes reddish. The dikes of grey granite, which cut the gabbro in many places in the neighbourhood, are probably connected with it.

The boundaries of this small granitic area are obscure, because the rocks in this region are very altered. Even in the best localities it is difficult to get fresh pieces of the granitic rock without blasting. This rock is composed of *micro-perthite, quartz, plagioclase, fayalite, biotite, hornblende,* and it has as accessory constituents *magnetite, apatite, fluorite* and *zirkon.* The most important constituents are microperthite, plagioclase and quartz.

Micro-perthite is present in anhedral crystals of varying sizes The largest attain 3,00 mm^2. The orthoclase, as well as the albite, is almost devoid of pigmentation. In many cases the peripherical regions of the perthite crystals are implicated with quartz; the central regions, being free from the last-named mineral, appear as a kind of nuclei, around which is formed the graphic interposition.

Quartz occurs for the most part in graphic intergrowths with perthite, and in independent crystals. The quartz-grains range in magnitude from very minute ones to those showing a section of 1,00 mm^2. The shapes are generally very irregular.

Plagioclase appears in zonally built crystals. Their composition ranges from oligoclase-andesine (Ab_{69} An_{31}) to albite. They occur in crystals of varying sizes. The largest are about 4,00 mm^2. This mineral seems to have separated before the quartz and perthite, but it always occurs in irregularly shaped forms.

Fayalite. There is observed a feebly pleochroic orthorhombic mineral with Y = yellow > X = bright yellow > Z = yellowish-white. 2 E is below 115°. Strong dispersion $\rho > \upsilon$. The sign is negative. Refringence high and birefringence very strong. It is probably fayalite. It shows two well-developed systems of cleavage, the one more distinct than the other. They are probably according to (010) and (100). It generally appears unaltered; sometimes, however, are observed the beginnings of decomposition, which then commences at the periphery, and the resulting mineral is lamellar and of a dark reddish-brown colour. Magnetite and serpentine are also observed as alteration products. The fayalite generally occurs surrounded by amphibole, in some cases also by mica. The crystals are always irregular, sometimes rounded. Their dimensions vary, ranging from very small grains to crystals with sections of 6,00 mm^2.

This occurrence in an acid rock, with a percentage of SiO_2 of, perhaps, nearly 70, is not common, when we take into consideration that in this rock the fayalite is the most important of the coloured minerals.

As WEIDMAN[1] points out, the rocks containing this mineral are always very poor in magnesia. In several slices from different parts of this granitic region fayalite is always present. Consequently, its presence can not be considered as casual.

The first occurrence of this mineral is noted from the island of Fayal, one of the Azores (PFEILSTICKER, Inaug. Diss. «Über den Fayalite» quoted by HINTZE).[2] It has been observed: in the Mourne Mts., Ireland; on Slavcarrach near Bryansford (in pegmatite); at Obsidian Cliff (in lithophyses in rhyolite), and at other localities in the Yellowstone Park (with quartz and a glassy feldspar); similarly on Lipari (in obsidian) (IDDINGS and PENFIELD, Am. Jour. of Sci., 40; 75; 1890). Also in Colorado at Cheyenne Mt. Probably it occurs together with the hafnefjordite of Iceland; probably also in the obsidian of the Cerro de la Navajas, Mexico (Rose, Pogg. 10; 323; 1827; IDDINGS l. c.), and at Rockport Mass. (in pegmatite dikes). It has been found in amphibole-granite, quartz-syenite and nepheline-bearing rocks in central Wisconsin, in the vicinity of Wausau (described by WEIDMAN). Manganiferous fayalite has been found in Agramer Gebirge, Hungary; Kišpatić (Abh. der Südslavischen Akad. 167, 1906); Zs., Kr. 45, 404. It was found in the product formed by the melting together of the andesite walls and the contents of an iron warehouse at St. Pierre, at the time of the eruption of Mt. Pelée, Martinique. The resulting slag consisted of a mixture of fayalite, magnetite and a little glass. In the cavities the fayalite was in isolated crystals; LACROIX, C. R., 136; 28; 1903; Zs. Kr.; 41; 106. All these data are quoted from DANA.[3]

HÖGBOM[4] describes occurrences of olivine in augite-syenite. According to him the olivine crystals sometimes occur included in quartz. He supposes that it is probably an olivine rich in iron, taking into consideration the alteration-products and the constitution of the rock, which, in spite of the large proportion of olivine, shows a very low proportion of magnesia. It is, then, very probable that it is fayalite.

In a Nordmarkite at Cerro Balmaceda, in the region of Ultima Esperanza, QUENSEL[5] has observed an olivine which has probably a fayalitic composition.

LUNDBOHM, in his monograph[6], says that in «gabbro-granite» at Vibyggerå occurs olivine. This is also probably fayalite. I shall describe

[1] The Jour. of Geol. 1904, p. 551.

[2] Handbuch der Mineralogie. II. 1, p. 24.

[3] Descriptive Mineralogy. 1911.

[4] Om Ragundadalens Geologi. Sv. Geol. Unders. N:o 182. Stockholm 1899, p. 44.

[5] Geologisch-Petrographischen Studien in der Patagonische Cordillera. Bull. of the Geol. Inst. of Upsala. Vol. XI. 1911, p. 41.

[6] Berggrunden inom Vesternorrlands län. p. 25.

below some granitic rocks in the parish of Nordingrå, and in Vibyggerå, which are fayalite-bearing.

Biotite. It is the common variety of this mineral that occurs in these rocks. The absorption formula is Z = Y = dark brown > X = pure yellow. The crystals are always irregular and of varying dimensions. Only in rare instances do they attain a magnitude of 1,00 mm^2. Sometimes appears surrounding fayalite.

Hornblende occurs in small quantities, for the most part surrounding the fayalite. It is a common hornblende with Z = dark olive green > Y = dark brownish-green > X = brownish yellow. Its dimensions are of the same order as those of biotite. The crystals are quite anhedral. Sometimes they contain many inclusions of magnetite, apatite, feldspar and quartz.

Apatite appears in small, subhedral crystals — and *magnetite* in irregular grains; sometimes in small rods. In part it is of secondary origin.

Fluorite is present in small, irregular, colourless grains and *Zircon* in subhedral crystals.

The relatively acid rocks north of the village of Ramsta pass over into quartziferous and olivine-bearing gabbros; the same thing happens to the north of the named region; in the neighbourhood of Öfvergård, and along the boundary of the Archæan, are found common gabbro-varieties, rich in quartz and orthoclase, and olivine-bearing.

The Parish of Nordingrå.

Geological features.

In the parish of Nordingrå occur, for the most part, Post-Archæan rocks, except for a small part of its western region, where appears an older formation.

In the western region of the parish, gabbro is predominant; in the eastern region occur anorthosites and the Post-Jotnian diabase — the latter covering the Jotnian quartzitic sandstone formation — and in the north, between the Firths of Omne and Ullånger, appear granitic rocks. In several places, but specially in the north, occur monzonitic rocks. The relations between the Sub-Jotnian and Jotnian, and between this latter and the diabase, are absolutely identical with those in the Ramsta region.

Ringkalleberget. — West of Sörleviken, in the northern region of Gaviksfjärden, appears Ringkalleberget, an interesting spot. The base of the hill is built up of Sub-Jotnian rocks, gabbro in the west and north and anorthosite in the north-east and east. In its eastern part, in the anorthosite region, appears some gabbro, intruding that rock.

These rocks pass over into arkoses. Over these lies the Jotnian sandstone, covered by diabase. The last rock forms the top of the hill.

The sandstone appears in the northern cape of Bäcknerholmen, an islet immediately to the south of Ringkalleberget, having there a width of about 50 meters. To the north-east of this locality, on the southern slope of that hill and about 400 m. from the southernmost cape, appears the sandstone of Ringkalleberget. From there I followed it, without break, to the northern slope of this hill. On the eastern slope of Ringkalleberget I did not see any sandstone, although I went up and down the slope of the hill, the whole way from the entrance of Sörleviken to the neighbourhood of the village of Kåsta, not only once but twice. Yet I cannot, of course, affirm that there is no sandstone there, just because I did not see it. In my map I have indicated sandstone on the eastern slope of Ringkalleberget because LUNDBOHM has observed it, and I have no reason to mistrust the observations of this able geologist.

For a distance of about 1 km. the sandstone borders the coast on the SW slope of Ringkalleberget. Where the slope of this hill bends to the north, at a place about 500 m. to the SE of the Cape of Dörnesta, the sandstone appears superimposed upon the arkose of the gabbro.

To the east of the Cape of Dörnesta the lowest strata of the sandstone lie at a height of about 35 m. above the sea, and the highest at a level of nearly 75 m.; its width is probably 150 m. Both contacts are hidden.

To the northward the sandstone slopes upward, so that on the northern slope, at a height of 100 m., we come upon arkose; between 100 m. and 125 m. the ground is covered with diabase-blocks. At the latter height the sandstone is observed, but at 140 m. it is hidden again by diabase-blocks. In this place it has a width of, perhaps, 60 m. and a thickness of about 50 m., and the diabase-covering has a thickness of nearly 70 m.

To the east of Sandviken (a bay to the south of the cattlesheds of Häggviken) the highest part of the Jotnian lies at 125 m.; the lower beds are hidden, but they probably occur at about 65 or 70 m. The probable breadth is 200 m. To the east of the cattle-sheds the upper layers of the sandstone are covered. The diabase *in situ* is found at about 125 m. and the arkose is observed at a level of 75 m. Further to the north, at a place SE of the small lake of Häggnor, the upper part of the arkose occurs at 90 m. and the contact between the sandstone and diabase at 145 m. above the sea.

On the NE slope of the hill the diabase is observed in contact with arkose at a height of 105 m.

The sandstone that appears on the eastern coast of Sörleviken is a continuation of the strata from Ringkalleberget. On p. 17 of his monograph[1] LUNDBOHM publishes a very illustrative profile across Ringkalleberget. In the direction of this profile the inclination of the strata is very slight, about 2 degrees. The dip is between 7° and 10° to the SE.

At about 200 m. from the two farms of Sörle the sandstone is observed close to the road, and a very fine-grained diabase 8 m. to the east, at an altitude of about 20 m. These are the upper layers of the sandstone. The lower ones appear 700 m. to the north. SSW of Barntjärn the highest layers of the sandstone are observed at 100 m. above the sea, and the lowest at 50 m.

On the southern shore of Nässjön the sandstone strata disappear in the lake. The south-eastern and eastern shores of Nässjön are built of diabase. The surface of Nässjön is at about 70 m. above the sea, and the upper sandstone-layers in the hill, close to its southern shore, were observed at nearly 100 m. The whole way the sandstone rests upon arkose. The top of the hill to the NE of Barntjärn consists of diabase

[1] Berggrunden inom Västernorrlands län.

and attains an altitude of about 165 m. The diabase appears superimposed upon the sandstone in the SE slope of the hill. The contact between the diabase and the sandstone is at about 120 m., and the latter rests upon an anorthositic arkose at 100 m. above the sea. The width of the sandstone region is about 50 m. On the NW slope of the hill, at a height of 120 m., the diabase appears in contact with the arkose, and, as is common in these cases, is very fine-grained.

North of Näs the sandstone first appears in Själandsklinten, the hill to the south-east of the village of Själand. When going up from Bäckland to the north one observes that the diabase, with a very steep slope to the west, apparently rests upon the arkose. Quite close to the slope, however, appears a talus of diabase-blocks. Perhaps a thin layer of sandstone is hidden by the talus. Själandsklinten attains an altitude of about 200 m. On its north-eastern slope appears a small sandstone region. The sandstone has a thickness of about 8 m. and it rests upon a labradoritic arkose at a height of nearly 140 m. The width of the sandstone is about 50 m. and the length nearly 100 m. The dip of the sandstone-layers is very variable, and in the northern part they are raised by the intruded diabase. It happens that layers of 30 and 50 cm. in width are included by the diabase. The anorthositic arkose shows a stratified structure, the big plagioclase crystals lying over on their flattened faces.

North of Själand I did not observe sandstone until I reached the region of Ulfviken, but LUNDBOHM has observed sandstone in the neighbourhood of Salberg.

The diabase appears limited to the west by a very steep escarpment running in a nearly S—N direction from Edsätterfjärden to the region NE of Salberg; at a distance of about two kilometers the direction of the escarpment becomes W—E for about two kilometers again, till the region of Ulfviken (a small bay in N. Räfsöviken) is reached. Along the slope is always observed a talus of diabase-blocks, detached from the slope above. On the southern coast of Ulfviken the sandstone is at sea-level, and it has a width of 150 m. The contact with the diabase covering is not visible, but it is probably at 35 m. above the sea. To the W of Ulfviken I did not observe sandstone; it appears in my map, however, in accordance with the observations of LUNDBOHM. Arkose was observed the whole way along the diabase wall.

On the east coast of N. Räfsöviken the sandstone appears from the southern part of the bay to the small bay east of Hamnmyrudden, where the layers are cut by a dislocation in about a N—S direction. To the SW of Hamnmyrudden the sandstone attains a breadth of nearly 170 m. The dip is about 7° to the SE.

In the region east of Hamnmyrudden, and surrounding the bay of Räflan, occurs anorthosite, intruded very intimately by aplitic veins. This occurs also in the region of Ulfviken, and west of it. Over the anorthosite appears arkose. This is well marked in the southern region of the bay and close

to the track which leads to the little farm of Räflan. The arkose has probably greater extension than that shown on the map. In many cases it is very difficult to determine if we are dealing with a decided arkose, because there are no defined boundaries between these rocks. To the east of the small bay by Skutudden (the bay east of Skutudden) appears a region of granite and of granitic arkose. The limits between them I have drawn quite arbitrarily, to show the relation between the rocks, but I am convinced that the greater part of the region is granitic arkose, and granite probably occurs only to a very limited extent.

At about 100 m. SE of Cape Katken, at the sea-shore, occur very altered granitic and anorthositic rocks, which may be considered as arkoses. To the SE of this locality the talus of diabasic blocks, which occur along the diabasic escarpment, extends right down to the shore; for this reason the sandstone cannot be seen.

To the south-west of the farm of Räflan the sandstone is observed at between 12 and 40 m. above the sea, lying over the anorthositic arkose. At a distance of nearly 500 m. to the south of Skälhälludden occurs a granite and granite-arkose region, which, in the map drawn by LUNDBOHM, appears as granite. This is the last observed occurrence of the Jotnian in the parish of Nordingrå.

Age relations between the Sub-Jotnian rocks.[1] The first rocks to solidify appear to have been the anorthosites. In the region of Vaviken, the bay NW of the village of Ulfvik, occur dikes of granite and of gabbro, cutting the anorthosite.

In the southernmost part of the peninsula which bounds S. Räfsöviken to the west, there occur two small regions of gabbro, which is sometimes porphyritic. The gabbro contains big fragments of anorthosite. The fragments are crossed by dykes of gabbro. The gabbro and the fragments are cut by two generations of acid dikes.

On the east coast of Vågsfjärden, to the WNW of Gåsnäs, is observed the contact between gabbro and anorthosite. The gabbro is medium-grained, but with smaller granularity than usual. In some places are observed gabbro-dikes running through the anorthosite.

On the southern shore of Storsjön, SE of Gåsnäs and near the road, are observed dikes of gabbro in anorthosite. The same thing appears at the contact between these rocks, in the neighbourhood of the village of Häggviken. The gabbro of the dikes is not fine-grained, but porphyritic. I could not detect any change in the granularity of the dike-rock at the contacts with the country-rock.

Consequently it may be stated with certainty that the anorthosites crystallised earlier than the gabbro.

[1] HJ. LUNDBOHM, Berggrunden inom Vesternorrlands län, 1899, p. 20 and 24.

Everywhere the granitic rocks occur cutting the gabbro and anorthosites. Beyond this, there is not a single example observed where a granite is crossed by dikes of the latter rocks.

At about 1 km. to the ENE of Bönhamn, in the northern part of an islet named Furan, occurs a small granitic region. In a direction from north to south it is about 30 m. and in the east-west direction nearly 60 m. across. The granite crosses the anorthosite in numerous dikes. Granitic dikes are, besides, a very common occurrence in the anorthositic regions.

One of the best opportunities for observing the relations between gabbro and granite is perhaps provided in the region to the north of Hyndtjärn, especially in the peninsula about 500 m. to the east of the sawmill of Salsåker. In the last-named locality occur well-developed eruptive-breccias, especially on the west coast of that peninsula. The fragments are of gabbro and the intrusive rock is granite. But it is not certain that this granite originates from that of the great massive. On the hills to the east of Östansjön occur the same kind of breccias. See Plate V, Fig. 2.

The monzonitic rocks are also crossed by granitic dikes. They seem to have crystallised about contemporaneously with the gabbro.

Consequently, the Sub-Jotnian rocks of the parish of Nordingrå have crystallised in the following order: anorthosite, gabbro and monzonitic rocks, and lastly granites.

Relations between the Sub-Jotnian and the Post-Jotnian rocks. Contacts between the Sub-Jotnian rocks and the Post-Jotnian diabase are often observed, and the latter always shows chilled margins.

A good locality for studying the contacts between anorthosite and diabase is in the western part of Älgsjöberget. The line of contact borders this hill on its western and northern slopes. The diabase is always aphanitic at the contact and cuts the anorthosite in dykes and veins. In the southern region of Högbonden the anorthosite is cut through by dikes of Post-Jotnian diabase. One of these dikes has a width of nearly 20 m. In the southern part of Höglosmen also occurs a dike of Post-Jotnian diabase.

The diabase is seldom observed in contact with gabbro. To the south of Bönhamn and NE of Flasen, close to a small lake, there occurs a small gabbro region which is cut by dikes of diabase. Moreover, the gabbro cuts through the anorthosite. Several dikes of diabase cut the gabbro in the region north of Dörnestaudden.

Contacts between the Sub-Jotnian granite and the diabase occur at Ramberget, between Norrfällsviken and Trollarviken. On the way from Hamnslotten to the south, at about 1,500 m. from the fishermen's huts, appears a diabase-dike of the width of about 30 m. This dike cuts through the peninsula from WSW to ENE (see map), and appears at the foot of the northern slope of a granitic hill. It follows the most developed system of joints of the granite and appears in so great a width because the dip is very small. The thickness of the dike is only about 2 m. Sometimes

it includes big granitic fragments. At the shore-line by Trollarviken it includes several small fragments of granite.

In slices of the contact between this dike and the granite occurs the same phenomenon as that described in connection with the basic dike-rocks of Ulfön. There is a zone in the dike-rock by the contact itself, where the porphyritic crystals of olivine, as well as of feldspar, occur in greater amount and with greater dimensions than those we find as we proceed inwards towards the centre of the dike.

At about 400 m. to the south of this dike appears the contact between the diabase of Ramberget and the granite. The former is afanitic at the contact, and becomes coarser at a distance from it. The diabase contains many granitic fragments, and has penetrated the other rock along the jointing-planes.

Thus, independently of the geological relations in the localities where the Jotnian occurs, it is shown by the contact features that the diabase is younger than the anorthosites, gabbro and granites. This is of interest, because there has been some doubt about this circumstance. As will be seen further on, the diabase always appears as the youngest rock among those occurring in great masses in this district.

The gabbro.

The gabbro of Nordingrå is described by LUNDBOHM on p. 13 of his monograph[1] as a «*fine-grained rock* which predominates in the region between Gaviksfjärden and Ullångersfjärden and consists principally of *plagioclase, diallage, hornblende, biotite, magnetite* and *apatite*. Besides, it sometimes contains *orthoclase* and *quartz,* though in small amounts. Now and then occur tolerably numerous, separated, white feldspar crystals, the rest of the rock being even-grained — a new variety having originated in this way. Generally the rock has a granitic-grained structure and the different minerals, with the exception of apatite, form irregular grains without crystallographic outlines; however, there are varieties with rather numerous tabular plagioclase individuals, scattered without regularity in a granitic-grained groundmass. In such cases the rock resembles a diabase in appearance, but it has not the latter rock's composition and it cannot be confounded with the olivine-diabase of the district.»

«At Sundsholmen in Vågsfjärden there are, in many places in the fine-grained gabbro, pegmatitic occurrences of rounded form with a width of from some centimeters to nearly half a meter. Near the contact they consist of fine-grained, augite-bearing rock, and in the middle of coarse-grained, red orthoclase and quartz.»

Besides the minerals found by LUNDBOHM, there are *olivine* and *orthorhombic pyroxene,* the latter mineral being much more common than the former, but both are very important constituents of some varieties.

[1] Berggrunden inom Vesternorrlands län.

Macroscopically, the most common variety appears as a dark grey medium-grained rock of uniform pattern, consisting of irregularly shaped crystals in juxtaposition.

The pattern of the rock may, however, vary within wide limits; it may be even-grained, or prophyritic, being connected by transitions with the coarse anorthosites of the district.

The *plagioclases* are white and generally unaltered. They occur for the most part in anhedral crystals of equant and tabular shapes, lying in all directions and flattened parallel to (010). They are always twinned according to the albite, the Carlsbad and the pericline laws. They show not the least traces of pigmentation, but nearly every crystal contains magnetite (in small euhedral crystals), apatite, and small, opaque needles of a mineral which is perhaps magnetite or ilmenite. These last inclusions sometimes occur in very great quantities, forming cloudy accumulations in the central parts of the crystals. In the even-grained varieties the crystals occur with sections of a little more than 1 mm.^{2}, but they may be much smaller or much larger. Sections of between 3 and 5 mm.^{2} are not uncommon. When the crystals are not equidimensional, as in this case, the basis of comparison is the area of the cross-sections.[1]

The plagioclases are zonally built. In sections parallel to (010) the extinction angle for the kernel was — 26°, and for the periphery — 8°, and, in one case, even 0°.

In sections perpendicular to X has been found an extinction angle of 32°, for the most basic region of the crystal. In Carlsbad twins upon the (010) face the extinction angle was 78°, for the most calcic part, and 108°, for the most sodic zone. Consequently they range from labradorites, Ab_{33} An_{67}, to andesines, Ab_{69} An_{31}. There are generally no abrupt changes in the optical orientation in the zonally built crystals, but a gradual transition from the kernel to the periphery.

Orthoclase was present in all the slices I examined, but in varying quantities. It occurs as one of the last minerals to separate, and, as a consequence of this, contains many inclusions of the other minerals. In some varieties very rich in apatite there are orthoclase crystals including this mineral in extraordinarily great quantities. It should seem that the other minerals, when crystallising, pushed away the apatite crystals, and the orthoclase, being the last to separate, must for this reason contain the apatite-crystals. As a consequence of this it may be understood that orthoclase must be the mineral with the most irregular shapes, with perhaps the exception of the quartz.

The orthoclase is nearly always without any pigmentation. Perthite has not been observed, but intergrowth with quartz occurs sometimes. The magnitude of the orthoclase crystals is very variable, and this in part

[1] Iddings, Igneous Rocks, Vol. I. — 1909. — p. 191.

depends upon the order of separation of that mineral. Now and then it attains 4 mm.^{2} in section, but in most cases occurs with dimensions of less than that.

Quartz is observed in small amounts almost everywhere in the gabbro region. It appears that the quantity of the quartz is always very variable, and, even in cases of localities separated by short distances, quartz may occur in one and not in the other. For instance, at the entrance to Häggviken, on its west coast, in Storberget, there is an abandoned quarry. The gabbro from this place is olivine-bearing and contains very little quartz (though I have seen two or three small grains in the slices); on the contrary, the rock of Gärdboberget, to the south of the entrance to Häggviken, and about 500 m. from Storberget, is comparatively rich in quartz and devoid of olivine.

It may be stated that the commonest variety is quartz-bearing. There are, however, many localities where the gabbro is quartz-free, as, for instance, in the region west of Körning.

When the quartz occurs in very small amounts, then it appears in the rock as very irregular grains, and was the last mineral to separate; but when its quantity is greater, it crystallises contemporaneously with orthoclase in graphic intergrowth. The quartz crystals are generally much smaller than those of the above-mentioned minerals, and their magnitude and form depend upon the form of the other minerals. It happens that several quartz-grains, separated by other minerals, show the same orientation, recalling to some extent the graphic texture, but there is no question of an implication, the quartz only filling the spaces between the other minerals.

Pyroxene. The pyroxene is in part monoclinic and in part orthorhombic.

The *orthorhombic pyroxene* is feebly pleochroitic, Z = pale green < Y = pale yellow < X = pale brownish-yellow. The difference between Y and X is slighter than that between Y and Z. The acute bisectrix is negative and perpendicular to (100). The maximum birefringence is about 0,013. So it is hypersthene.

The angle of the optic axes is not large (about the same as that of diallage). The hypersthene generally appears in anhedral crystals. In the rock at Storberget (Häggviken) it surrounds the olivinegrains, and in most cases the plagioclases show independent outlines against the crystals of orthorhombic pyroxene.

It plays an analogous rôle to that of the augite in some diabases where this mineral occurs in such proportions that the crystals form a matrix to the plagioclases. It is often interpenetrated by diallage. Occasionally occur several large crystals with the same orientation. This phenomenon is similar to what takes place in the case of augites in some diabases.

In most cases their magnitude is greater than that of the p agioclases. Sections of 4 mm.^{2} are not uncommon, but there may be ob-

served all the intermediate sizes between such large grains and very minute ones It sometimes happens that the section of a single individual, embracing a surface of more than 10 mm.^{2}, contains many crystals of plagioclase, olivine and magnetite surrounded by biotite. In sections parallel to (100) there is, in many cases, a kind of lamellar structure. In such cases the interference figure is very distorted.

The *monoclinic pyroxene* is *diallage*, which occurs in varying amounts, sometimes less in section than hypersthene, sometimes greater, with its typical, well-developed cleavage, parallel to (100). Like the orthorhombic pyroxene it has no independent crystal shapes, but fills the spaces between the other minerals (excepting orthoclase and quartz). All that has been said about the forms of the hypersthene crystals is true of the diallage.

The pleochroism is very feeble, even in thick sections of 0,03 and 0,04 mm. The angle of the optic axes seems to be that which is common in diopside. The axis A' (A of ROSENBUSCH) shows evident dispersion, but not the axis A (B of ROSENBUSCH). This mineral is probably of diopsidic constitution. The colour is pale green. The diallage occurs very intimately intergrown with orthorhombic pyroxene, and the latter is also overgrown by the former. Especially is a lamellar intergrowth common. Twinning is not very common. The twinning plane is parallel to (100). There occurs very fine lamellation parallel to (001).

Opaque minerals in elongated forms are often observed in the direction of cleavage, and occupying just the cleavage cracks. It happens that some of these crystals are surrounded by a very narrow corona of biotite. Perhaps this opaque mineral is magnetite or titaniferous magnetite. Sometimes the included grains are not elongated, but rounded.

The common alteration-product of diallage is hornblende, and sometimes serpentine. It lies in a direction from the periphery inwards, and along the cleavage cracks, the diallage crystal being replaced by a single amphibole crystal.

The magnitude of the crystals of this mineral is about the same as, or perhaps somewhat less than, that of hypersthene.

Olivine occurs in nearly all varieties of this rock, even in the more acid kinds. It has generally a whitish-yellow colour, with sometimes some pleochroism between white and brownish-yellow. It occurs in most cases as anhedral, rounded crystals, with sections of about 0,50 mm.^{2} They are very often surrounded by the orthorhombic pyroxene. The optic angle 2 E is larger than 115°, but not much larger, and the sign is negative; dispersion strong $\rho > \upsilon$. Inclusions are common, the included minerals being apatite, magnetite and sometimes even feldspars. The common alteration-products observed in the olivine of this rock are serpentine and magnetite. The importance of the last mineral as an alteration-product, together with the pleochroism, the axial angle and its sign, support the supposition that it is a variety very rich in iron. It may be stated that the pleochroism was most noticeable in a slice of the thickness of

about 0,04 mm. from gabbro observed in the region of Håll (Nordingrå). This gabbro has relatively much quartz. The colours were: Z = yellowish-white < X = pale yellow < Y = brownish-yellow. In the gabbro west of the village of Håll the olivine occurs surrounded by biotite, in the same way as the latter mineral surrounds magnetite. It happens that the olivine of this rock is extraordinarily irregular, appearing in large crystals with many ramifications, and that several large crystals have the same orientation — this circumstance recalling pyroxene.

Biotite occurs in small quantities, but it is always present. The pleochroism is Z = Y = dark reddish-brown > X = yellow. I have found in the same slice some crystals quite uniaxial, and others with an axial angle 2 E of about 40°. This was in gabbro found in the region of Jeresta.

Biotite appears in part as independent, very irregular grains of varying magnitude, but generally small and surrounding magnetite. In some cases it is altered to a green biotite. It has been observed implicated with pyroxene. Twinnings according to the mica law present themselves sometimes.

Amphibole. In the common gabbro of Nordingrå this mineral appears secondarily, and consequently is not present at all in fresh rocks.

It is a green-brown variety of common hornblende, with Z = dark olive-green > Y = dark brownish-green > X = yellow. Besides this, occurs an actinolitic variety, with less pronounced pleochroism and somewhat higher birefringence.

Of course, the magnitude of the hornblende crystals depends upon the conditions of alteration of the rock, and they may attain the same magnitude as those of the original pyroxene.

Apatite is a very important accessory constituent. In nearly all varieties it occurs in rather large amounts, in part as long, fine prismatic crystals, and in part in the form of shorter, rounded grains. As has been mentioned above, it happens that orthoclase contains accumulations of this mineral in very small crystals. When in long crystals it shows quite euhedral shapes, but the shorter, rounded grains are subhedral and anhedral. Crystals of the length of 1 mm. are not uncommon, the width being about 30 times less.

Magnetite is always present, principally as a primary constituent, but in part as a secondary product. It appears in large, irregular grains of about 1 or 2 mm.^{2}, and in smaller, rounded inclusions in other minerals.

There are rods of a mineral like magnetite; perhaps it is ilmenite. The crystallisation of the magnetite has sometimes followed that of the apatite, but in other cases it has solidified after the plagioclases and other minerals.

Pyrrhotite often occurs, but in reduced amounts, in the form of inclusions, especially in pyroxene. The occurrences of pyrrhotite are occasionally large, but of no practical importance. Accumulations of this mineral are very common along the limit between the gabbro and the Archæan. Con-

sidering the mineralogical composition, this rock takes a place between the gabbros and the norites. Taking into consideration the probable composition of the olivine of this rock it seems probable that this gabbro is rich in iron and poor in magnesia. ROSENBUSCH,[1] when dealing with this rock, on p. 74 writes: »Es wäre zu untersuchen, ob der gabbro etwa zu den Essexiten gehört, wie in Massachusetts und bei Montreal in Kanada». This gabbro probably contains too small amounts of alkalies to be classed among the essexites.

This gabbro is a millimeter-grained rock. For the most part the fabric is seriate homeoid, and in some cases seriate porphyroid.

The order of separation of the minerals varies somewhat in different parts of the gabbro region. Always the first mineral to crystallise is apatite, and then, as a rule, follow magnetite, olivine, biotite, plagioclase, pyroxene, orthoclase and quartz. In most cases the plagioclase has separated before the pyroxene, and it appears that, when the difference of age is relatively great, the plagioclase crystals have a more decided tendency to become tabular in shape. The olivine has, in most cases perhaps, crystallised before the plagioclase, but not always. This perhaps depends upon the same circumstances as obtain in the Post-Jotnian diabase, where it is evident that the order of separation depends upon the degree of saturation of each mineral in the magma. In the diabase the phenomenon is clearer, because there we have extreme forms of differentiation, which do not exist in this gabbro.

There are varieties with the most typical gabbro-fabric, which ROSENBUSCH calls »hypidiomorph-körnige». The pyroxene then occurs in rounded, tolerably large grains, which happens when the gabbro contains lesser amounts of plagioclase. But, in the same measure that the plagioclase increases in quantity, the rock loses that fabric and becomes more diabase-like. The sequence in the crystallisation of the minerals in the different varieties of this rock is, consequently, not in accord with the order of separation given by ROSENBUSCH[1] for the gabbro-rocks, but it is in accord with the results of MOROZEWICZ, MEYERHOFFER, VOGT and others.

The Anorthosites.

LUNDBOHM describes the anorthosite on p. 13 of his monograph[2], and calls it «coarse-grained gabbro». His description is as follows: «The coarse-grained gabbro appears, as shown in the map, principally surrounding the diabase north and south of Edsättersfjärden, and between Sörleviken and Omneviken, in the parish of Nordingrå. This rock is of a somewhat

[1] Microscopische Physiographie der Massigen Gesteine. Erste Hälfte. Tiefen Gesteine, p. 365.

[2] Berggrunden inom Vesternorrlands län.

different structure and constitution from that of the fine- and medium-grained varieties. It generally consists of thick, tabular plagioclase individuals of 2 cm., or even more, between which lies a ground-mass (mellanmassa) of dark minerals, which in respect to quantity plays a subordinate rôle. Over rather extensive areas the plagioclase is quite fresh, translucent, greyish-brown to green and in other cases very altered, of a greenish-grey colour and opaque, and the rock assumes quite a different, more variegated appearance. The dark minerals principally consist of diallage and hornblende — the latter secondary for the most part — biotite and titaniferous magnetite in rather large grains. Besides this, chlorite and epidote often occur. Olivine has not been detected with certainty, but quartz has been observed, though in very small amounts.» On p. 20 he remarks: «The east coast of Räfsön affords good opportunities for studying the relations between the different gabbro-types and the diabase. Räfsön's southern part, along to a bay named Måbergsviken, consists for the most part of the common, coarse-grained gabbro, but together with this rock occurs a medium-grained one, which appears to be younger, because sometimes it occurs as dikes in the other, or includes fragments of it. The gabbro is cut by a swarm of dikes and veins of granite, sometimes in such numbers that the whole gives the impression of a breccia. Such dikes and veins do not occur in the diabase. At the foot of Högmoberget appear both gabbros, the granite and the diabase, in contact with each other, and apophyses of the latter cut the other rocks.»

In the slices I studied the anorthosites consist of *plagioclase, orthoclase, quartz, diallage, olivine, magnetite, apatite, biotite* and *pyrrhotite* as primary constituents, and *amphibole, chlorite, serpentine* and *magnetite* as secondary constituents.

The *plagioclase* is the most important mineral. It generally occurs in subhedral and anhedral crystals of great size. They are usually tabular according to (010). On (010) they attain dimensions of about 4 cm.^{2} Such a crystal may be of 1 cm. in width, or something more, in the zone perpendicular to (010). Twinning is always present and is of the albite, pericline, or Carlsbad type. The chemical composition is that of labradorite. I have found a somewhat varying composition in different regions of the district. In the region of Räfsön the labradorites have a composition $Ab_{40}An_{60}$. The determinations were made by the extinction angles on sections from the zone at right angles to (010), (when the albite twinning is combined with Carlsbad twinning), by the «statistical method» and in flakes parallel to (010), the results being in accord. From the same region, in sections parallel to (010), I found an extinction angle of only $-16°$ ($Ab_{50}An_{50}$), and the same measurement was obtained for the same mineral occurring in anorthosite from Högbonden. In anorthosites from Gåsnäs I found an extinction of $-22°$ on (010). The above-mentioned dimensions of the crystals are only the average ones. They vary within wide limits. It is the labradorite that gives its colour to the rock. The differences in colour depend upon the state of alteration of the rock.

When fresh it presents shades of white, and the appearance of the rock at some distance is somewhat greyish. If the labradorite is altered it exhibits greenish and yellowish shades. In thin sections the colour is white. The alteration of labradorite is principally to kaolinite, prehnite, epidote and zoisite. It can be followed through all the transitions between quite fresh to very altered, especially in the regions where arkoses occur. The labradorite in the arkoses becomes nearly opaque as a consequence of alteration. Inclusions of an opaque mineral in acicular crystals are very common. Perhaps it is magnetite. These inclusions are always parallel.

Orthoclase occurs in small amounts, generally somewhat red-pigmented. In nearly all the varieties orthoclase is observed in irregular grains. This is the consequence of the fact that this mineral, together with quartz, was the last of the constituents of the rock to crystallise.

Quartz is nearly always present in small quantities. Sometimes it exceeds the orthoclase in amount and sometimes vice versa. Graphic implication between these minerals is common. Quartz and orthoclase appear, filling the spaces between the other minerals. It happens that the big plagioclases are separated by long and narrow, irregular layers of quartz, or orthoclase, or of both, cementing them together. And sometimes occur quartz grains included in plagioclase, and even in magnetite, with the same orientation as the surrounding quartz. As the crystallisation of the last-mentioned minerals began much earlier than that of the quartz, the above circumstance may be explained by the suppositon that the included quartz appears in the peripherical regions of those crystals. In other slices it happens that plagioclase shows graphic implication with quartz in the peripherical regions. Then it may be stated that, at least in some cases, the crystallisation of the plagioclase was not ended when the quartz began to solidify.

Diallage is a mineral which is always present in all varieties, excepting some anorthositic inclusions, where the only essential mineral is labradorite. It is exactly similar to that described from the gabbros, but does not occur in the same way. In the anorthosites it generally occurs in anhedral, somewhat rounded grains of dimensions of between 1 and 4 mm.^{2}, but it never shows those large and ramified crystals that it does in the gabbro. Sometimes it appears obstructing the development of the plagioclase crystals, but that is only in their peripherical regions.

The same kind of acicular inclusions as those mentioned in the description of the plagioclases occur in diallage. These inclusions are of a black mineral. Their length is generally less than 0,075 mm. The commonest alteration is to hornblende. In my opinion this hornblende is not the consequence of a dynamo-metamorphic influence on this rock; at least not of dynamo-metamorphism to any extent. The quartzes, for instance, do not show more signs of pressure than in the granitic rocks. As I have pointed out in the chapter on the age of the rocks of the district, there are uralitic rocks younger than the Post-Jotnian diabase, and

all the authors who have studied the last-named rock agree that it is entirely without the least sign of pressure. Serpentine also occurs as an alteration-product of the pyroxene. In most cases the kernels of the diallage crystals are quite fresh, only the outer portions of them being altered.

Olivine occurs in less quantity than diallage, in anhedral, rounded grains, showing sections of dimensions varying between 1 and 7 mm.^{2}. It is somewhat pleochroitic, and its general appearance is that of an olivine very rich in iron. Generally it is surrounded by hornblende and serpentinic products, but seldom by diallage. After the plagioclase it is the mineral which occurs in the largest crystals, but they are not numerous. Olivine occurs in nearly all unaltered anorthosites which are not composed solely of feldspars. The alteration is the ordinary alteration of olivine. Inclusions of magnetite and apatite are common. The former may sometimes, perhaps, be secondary.

Magnetite appears in anhedral crystals. The largest sections have dimensions of between 1 and 2 mm.^{2}, but they are generally less than 1 mm.^{2} Sometimes they are surrounded by an envelope of biotite. In some cases appear relatively large accumulations of magnetite.

Pyrrhotite occurs very sparingly, in anhedral crystals.

Apatite occurs in nearly all the varieties of this rock I studied. The crystals are generally subhedral, in some cases euhedral. It was the first mineral to separate, and, consequently, is enclosed by all the other minerals. Generally the crystals are microscopical, but crystals of a length of 2 mm. are not uncommon; in one case I measured a crystal, cut parallel to the axis, which showed a length of 3 mm and a breadth of 0,10 mm. This crystal was terminated by pyramidal faces. Even in the varieties of anorthosite almost devoid of any dark mineral, I have observed apatite in macroscopic (2 mm. in length and 0,5 mm. in breadth) and rather numerous crystals. After the feldspars and quartz it was the most important mineral. I refer to this observation because some authors consider that apatite occurs more sparingly in the feldspathic rocks. For instance, IDDINGS[1] says that it is generally more abundant in the less feldspathic, highly ferro-magnesian rocks. ROSENBUSCH[2] expresses the following opinion: . . . «sind daher auch reichlicher in den sog. basischen Konkretionen der Tiefengesteine, als in den normalen Gesteinformen vorhanden. — Ebenso reichert er sich bei der Spaltung der Tiefengesteinsmagmen auffällig in den die Al-freien Kerne enthaltenden Teilmagmen an, daher seine Häufigkeit in den theralitischen Magmen gegenüber den foyaitischen, und in den lamprophyrischen Ganggesteine gegenüber den aplitischen.» The same author, when treating of the anorthosites[3], writes: «Von den reinen Labradorfelsen, welche herrschend rötliche bis violette Farbe haben, und

[1] Rock Minerals. — New York 1906, p. 478.
[2] Mikroskopische Physiographie der Mineralien. Stuttgart 1905. p. 108. Zweite Hälfte.
[3] Mikroskopische Physiographie der Massigen Gesteine. 1907 p. 356. Erste Hälfte.

nirgends Apatit führten ...» Of course I do not mean to say that in general the petrographers referred to are not right, but I wish to point out that there may be exceptions, as in the case of the rock described here. This is from a dike of a very feldspathic rock, which crosses the common anorthosite, containing dark minerals, immediately to the north of Löf's farm in Gåsnäs, Nordingrå.

Biotite occurs in varying amounts. From some varieties it is almost absent, in others it appears surrounding the magnetite, but always in small quantities. It is of the same variety as that occurring in the gabbro.

The quantitative mineralogical composition is very variable in these rocks, and the same may be said in respect to the texture. In all cases the rocks are phanero-crystalline. There are centimeter-grained and millimeter-grained varieties. In the majority of cases they are coarse-grained. The fabric varies. Those varieties composed almost solely of plagioclases are nearly equigranular. On the contrary, those containing dark minerals show an inequigranular fabric. They may vary between seriate homeoid and seriate porphyroid fabrics. As has been mentioned above, the graphic fabric is sometimes observed, but never plays a prominent rôle. It occurs in part as a result of the implication of orthoclase and quartz, and in part as a consequence of the intergrowth of plagioclase and quartz.

Inclusions of an anorthositic rock of triangular section, and almost free from dark minerals, are often observed in these rocks; only rare occurrences of magnetite are observed, and then they are surrounded by biotite. These triangles are sometimes quite regular. The plagioclases are very altered, like those of the including rock, in kaolinite, prehnite, albite, quartz and epidote. In these inclusions apatite has not been observed. »Schlieric» dikes, and even true dikes, generally of a more feldspathic variety than the country-rock, occur very often. The texture of these rocks is quite analogous to that of the anorthosites occurring in great masses. Perhaps the former are more equigranular than the latter, especially in those inclusions composed only of plagioclase.

Dike-rocks.

Pegmatites. At about 500 m. to the south of Räfsön quay appear pegmatitic dikes, cutting the anorthosite. The contacts with the anorthosite are hidden. This rock is very coarse-grained, and is composed of *orthoclase, albite, perthite, quartz, pyroxene, apatite, magnetite, biotite* and *hornblende.*

Orthoclase occurs in great quantities, in places implicated with albite. It is coloured by a red pigment. The implication with albite is very intimate, as in common perthite and in large interpenetrations. But it may be stated that all the minerals are intergrown in the latter form.

Quartz occurs in graphic implication, and does not present any par-

ticularly noteworthy features. The inclusions are very numerous. No pigmentation of any kind has been observed.

The *Plagioclase* shows lower refraction than does Canada balsam, and the extinction angle on (010) is about 20°, so it must be albite. Sometimes it is somewhat red-pigmented, but not so much so as orthoclase.

Pyroxene is perhaps the mineral that occurs in the largest crystals, which occasionally attain a length of over 20 cm. in the direction of the c-axis. The angle of the optic axes appears to be the same as in augite and diopside. The sign is positive. It is much altered into hornblende, and this renders its certain determination difficult. My opinion is that probably we are in the presence of a diallage like that occurring in anorthosites and gabbro.

All the minerals named occur interpenetrated with each other, and, if this is a necessary condition of crystallisation for a pegmatite, the rock in question is a true pegmatite. But the field observations gave as a result that the proportions of the different minerals vary between wide limits. This is a peculiarity common to nearly all pegmatites. Sometimes in these dikes at Räfsön it is observed that orthoclase, plagioclase and quartz predominate in the rock, which contains pyroxene in relatively small amounts; but in other cases pyroxene is present in as great, or greater, quantities than all the other constituents put together.

Hornblende seems to be only a secondary product of the pyroxene. There occur, however, two kinds of hornblende, one is brownish and the other shows more greenish shades. Great accumulations of hornblende, biotite, magnetite and apatite occur. The crystals are anhedral and oriented in all directions.

Biotite appears in sections of 3 or 4 mm.^{2} The pleochroism is Z = Y = dark brown > X = yellow. It is generally somewhat altered in the ordinary way.

Apatite generally occurs in small, well-faced crystals. Exceptionally are observed sections as large as (1,12×0,22) mm.^{2}

Magnetite is present in small quantities. The crystals are irregular and the sections sometimes attain dimensions of nearly 1 mm.^{2}

When considering a rock of a fixed qualitative mineralogical composition, but with constituents occurring in different proportions in different places of the rock-body, we shall find — in some localities where the minerals appear in certain proportions — a eutectic mixture, and the crystallisation will be simultaneous, but in other places there must be a regular sequence in the separation of the constituents. For this reason it appears to me to be not quite legitimate to consider the simultaneous crystallisation of the constituents as a test for determining whether a rock shall be classified among the pegmatites or not.

In the pegmatites at Räfsön it sometimes happens that quartz appears in relatively great amount; sometimes it is implicated with feldspars. The feldspars sometimes occur without any interpenetration with quartz. The

pyroxene is sometimes interpenetrated with orthoclase and quartz, in some instances in the outer parts of the crystals only, which probably shows that the kernel crystallised before the quartz and orthoclase began to separate, and that when the eutectic proportions were reached the whole separated at once.

The order of crystallisation in this rock, in varieties containing much pyroxene, appears to be as follows: apatite, magnetite, kernels of the pyroxenes; then the rest of the pyroxene, and feldspar and quartz simultaneously.

The granularity of this rock is between centimeter-grained and decimeter-grained. The fabric is inequigranular and graphic. The crystals are irregularly shaped, excepting the apatite crystals.

Whether this rock is a pegmatite of the anorthosite or of the gabbro I cannot determine, but I think this question is one of secondary importance, taking into consideration the consanguinity of those rocks. Usually the minerals that go to compose pegmatites are those which are last in the sequence of the crystallisation of the parent magma. We have here alcalic feldspars, quartz and diallage as the principal constituents, and it is just these minerals that separated last in the anorthosites, as well as in the gabbro-rocks. The order of separation in the pegmatites has also been the same as in the rock in question. First crystallises the excess over the eutectic proportions, in the form of apatite, magnetite and some pyroxene, and afterwards the eutectic mixture solidifies at once.

As far as I know, such anorthosite-pegmatites have not been described before, although we find descriptions of gabbro-pegmatites composed of labradorite and hypersthene, and of others composed of oligoclase, quartz, muscovite, biotite, almandite etc.

Granitic dikes, micro-pegmatitic veins, and aplites. In the region to the south of the place where the above-described anorthosite-pegmatites occur, the anorthosite, as well as the gabbro, are cut through by dikes composed of a reddish, granitic rock. The dikes are generally narrow, but sometimes they attain a width of two or three meters. The rock consists of *orthoclase, quartz, plagioclase* and *mica*. Magnetite occurs as an accessory constituent. Apatite has not been observed. The minerals are mentioned in the order of the proportions in which they appear.

Orthoclase is the mineral occurring in greatest quantity. It is red-coloured and appears in anhedral crystals, whose forms depend upon those of the other minerals. The dimensions of the sections are between 1 and 3 mm.^{2}

Albite occurs in sections as large as those of the orthoclase. The albite-crystals are also anhedral, and appear to have separated before the orthoclase, because they occur as inclusions in the latter.

The *quartz* is included in the feldspars and occurs in rounded grains, whose sections are generally less than 0,3 mm.^{2} in area.

Mica occurs in irregular flakes, flattened parallel to (001), and the axial angle is 0°. It is somewhat altered to a reddish-black mineral.

The absorption is Z = Y = nearly opaque, X = yellow. This is in ordinary slices of about 0,02 mm. in thickness, but in thinner flakes Z and Y are = brownish-yellow with greenish shades. In this rock there is an evident sequence in the crystallisation: first mica and afterwards quartz, albite and orthoclase.

This rock has a somewhat aplitic character, but it would perhaps be inconsistent with the accepted criteria in qualitative classification to consider it as an aplite.

The aplites are characterised by a saccharoidal texture: «sie besitzen mehr oder weniger isometrische Ausbildung der Gemengteile und sind sehr arm bis nahezu frei von farbigen Elementen».[1] In this case biotite occurs in rather large proportions, and there is a marked sequence in the separation of the constituents. It appears that the texture of this rock is what ROSENBUSCH calls «hypidiomorph-körnige» but not «panidiomorph-körnige Struktur»,[2] the latter texture being that typical of the aplites, according to the author quoted.

These dikes are intruded by micro-pegmatitic veins. Their qualitative constitution is like that of the above-described dike-rock, except for albite, which does not occur. The *orthoclase* crystals are large and show sections of 35 mm.^{2}, but the implicated quartz generally appears in very small grains. The orthoclase crystals are reddish-pigmented and irregular in shape. It happens that some orthoclase crystals are only partially implicated, and the limit between the implicated and the non-implicated regions of the section is almost a straight line. As has been mentioned, the *quartz* always occurs in graphic intergrowth with orthoclase. There appear some relatively large, rounded grains, with sections of about 6 mm.^{2}, but they also form part of the implication. There occurs another variety of micro-pegmatite with a coarser texture.

Biotite is the only dark mineral contained in the rock, and appears in large crystals, with a surface on (001) of about 100 mm.^{2} They are, however, flattened parallel to this face. Their thickness is 1 or 2 mm. The absorption is identical with that of the above-mentioned mica from the aplitic dike. Biotite has been the first mineral to crystallise, and occurs in subhedral crystals. The crystallisation began with the separation of mica, and was followed by a simultaneous solidification of orthoclase and quartz. The intrusion of this pegmatite appears to be contemporaneous with the crystallisation of the aplitic magma, because in many places the contacts are not sharp, and the pegmatite blends into the other rock. That is what IDDINGS[3] very properly calls *contemporaneous veins*.

Such rocks are very often observed in other regions of the anortho-

[1] Mikroskopische Physiographie der Massigen Gesteine von H. ROSENBUSCH. Erste Hälfte. 1907. p. 579.

[2] Elemente der Gesteinslehre. p. 57.

[3] Igneous Rocks. Volume I. New York 1909. p. 272.

site and gabbro areas. Sometimes they are not reddish in colour, but greyish and perthite-bearing.

In the hills near the east coast of Vågsfjärden occur many narrow dikes of a grey-coloured, aplitic rock, which consists of *micro-perthite, albite, quartz* and *biotite.*

In one of these dikes near the contacts appears a zone which only consists of spherulites, produced by graphically intergrown quartz and micro-perthite. The spherulites are very fine-grained in the centre, but the grains increase in size towards the periphery. In the central parts of the vein the rock has a nearly aplitic texture.

The *quartz* generally appears with more independent outlines than the feldspars, and is included by the latter. The largest quartz sections have an area of somewhat over 1 mm.^{2}, and the smallest grains may show sections with a diameter of about 0,01 mm. The quartz crystals generally show signs of stresses of some kind, because the directions of the vibration of light are not the same for all parts of the crystal.

Albite occurs in lesser amounts than quartz and orthoclase. The sections of this mineral attain an area of 4 mm^2. The crystals are anhedral, and are sometimes surrounded by a micro-pegmatitic corona.

The *micro-perthite* is the most common constituent, and occurs in crystals whose sections are between 1 and 3 mm.^{2} in area.

Biotite. — The pleochroism is Z = Y = dark brown and X = yellow. It occurs in anhedral crystals, flattened parallel to (001). The sections are generally less than 1 mm.^{2} in area.

Here and there, filling the spaces between the larger feldspar crystals, appears a fine-grained micro-pegmatite. Very often the outer parts of the feldspar crystals are implicated with quartz.

In the central parts this rock is millimeter-grained, and the fabric is very nearly seriate homeoid. In the contacts with the country-rock the fabric is spherulitic, the spherulites consisting of graphically intergrown quartz and perthite. The texture of this rock varies between those of aplite and micro-pegmatite.

Along the contact walls it is observed that the dike-rock has sometimes included labradorite crystals of the anorthosite. This process has been quite mechanical, the large labradorite crystals being easily separable from the rock-mass.

A dike-rock in the region of Hållsjön consists of *micro-perthite, albite, quartz, biotite* and, as accessory constituent, *apatite. Magnetite* has not been observed.

The *perthitic* sections attain an area of about 4 or 5 mm.^{2} and are always anhedral. Carlsbad twins are often observed.

The *quartz* in some cases shows sections of about 2 mm.^{2}, but generally they are less than 1 mm.^{2} in area. It commonly occurs in anhedral and somewhat rounded grains, sometimes including feldspars, but the feldspars contain quartz inclusions, too, of which the extinctions are undulated.

Albite appears in anhedral crystals, with sections of about 1 mm.^{2}, in lesser amounts than the above-named constituents. It appears to have separated before the quartz and perthite.

Biotite is of the same kind as that in the above-described rock, and occurs sometimes in euhedral crystals of very small dimensions, and the larger crystals occur, for the most part, in irregular flakes. The few euhedral crystals observed show an area on (001) of 0,01 mm.^{2} and occur included in quartz. Sections of mica attaining an area of 1 mm.^{2} are very seldom observed. The biotite is often altered to a green variety and has been the first mineral to separate.

Apatite occurs in very small, subhedral and anhedral crystals. This rock may be considered to be millimeter-grained. The fabric is seriate homeoid.

This dike cuts the gabbro in a hill which lies west of the village of Vennersta, and it can be observed immediately to the north of the road on the way from Vennersta to Hållsjön. Such dike-rocks are very common in the gabbro region. They are biotite-aplites, and never contain hornblende. The accessory mineral is apatite. Magnetite has not been observed in any of the slices from different localities in the district.

Mixtures between Granite and Anorthosite.

Over wide regions of the gabbro and anorthosite areas, and more especially in the neighbourhood of the boundaries with the granitic masses, there occur granitic dikes, which in all probability originate from the great granitic bodies. At least, their composition is very similar, and when a contact, or the contact region of the gabbro or anorthosite, with granite, is studied, it can always be observed that the granite is intruded into these rocks. On the eastern shore of Räfsön the anorthosite is cut through by numerous dikes of a reddish granitic rock, which consists of *orthoclase, albite, quartz* and *hornblende,* as essential minerals, and *magnetite, apatite* and *zircon* as accessory constituents.

The *orthoclase,* as is usual in these rocks, is reddish-pigmented, and occurs in irregular grains with sections of about 1 mm.^{2} in area. It contains inclusions of the named accessory minerals.

Albite generally occurs in crystals of about the same dimensions as orthoclase, but sometimes in crystals of greater dimensions, which give to the rock a porphyritic appearance. The porphyritic crystals show sections parallel to (010) of an area of between 15 and 20 mm.^{2} The albite crystals, like the orthoclase, contain inclusions of hornblende, magnetite, zircon and apatite.

The *quartz* occurs in irregular, somewhat rounded grains. The sec-

tions of this mineral have an area of between 0,5 and 1,0 mm.^{2} The extinction is undulatory.

Hornblende is a common hornblende, with the absorption formula Z = dark green > Y = green > X = greenish-yellow. The sections generally show an area of less than 1 mm.^{2}, but in rare instances they attain an area of 2 mm.^{2} It sometimes appears somewhat chloritised. The crystals are always anhedral.

Magnetite is the most common of the accessory constituents and seems to be titaniferous. Sometimes it occurs together with very altered hornblende crystals, and perhaps it is then of secondary origin. The sections are, in many cases, of about 0,50 mm.^{2} in area, but generally less. The crystals are quite anhedral.

Zircon. — This mineral appears in euhedral crystals, which, in sections perpendicular to the axis, show an area of about 0,03 mm.^{2}

Apatite occurs in small, anhedral and subhedral crystals included in all the other constituents, excepting zircon. Its dimensions are somewhat less than those of the last-named mineral.

The granularity of this rock is between decimillimeter-grained and millimeter-grained. The fabric is inequigranular and may be classed as seriate porphyroid.

Analogous rocks are those occurring in the region of Ulfviken and Räflan, in the southern part of Omnefjärden, cutting through the anorthosites. The latter rocks are invaded by a swarm of dikes and veins of granitic and aplitic constitution.

The boundary between the anorthositic and the granitic masses is very probably quite close to the southern shore of Omnefjärden. This supposition is supported by the fact that, in the north-eastern region of Räflan, the granite appears occupying a small area. This granite is probably all one with the great body of the northern region of Omnefjärden. Moreover, the small islets, Örarne, Skorpan and Gåsen, also consist of granite. The anorthositic rocks are completely metamorphosed in some cases. The granitic magma has penetrated into them, in such a way that the labradoritic crystals appear as phenocrysts in a groundmass principally composed of orthoclase, albite and quartz; moreover, chloritic accumulations occur together with magnetite and apatite. LUNDBOHM[1] specially mentions the rocks occurring to the south of Katken, but they are very altered. As more suitable for petrographical researches I consider the analogous rock at Skälhälludden, described by HÖGBOM,[2] which is always at least somewhat altered, but not so much as the occurrences south of Katken.

A more important difference between this granite, which invades the anorthosites so intimately, and that which occurs in dikes is that the for-

[1] Berggrunden inom Vesternorrlands län, 1899, p. 19.

[2] The igneous rocks of Ragunda, Alnö, Rödö and Nordingrå, p. 22, and Precambrian Geology of Sweden, 1910, p. 16.

mer, now and then, shows a graphic texture, and that its hornblende is replaced by accumulations of irregular hornblende crystals, chlorite and magnetite; moreover, it contains a comparatively large amount of apatite in large and regular crystals.

The labradorite crystals have been metamorphosed by the intrusions in several ways. It appears that it is relatively easy for an intruding magma to disintegrate the coarse anorthosites. In several cases I have observed that aplitic dikes have loosened entire plagioclases at the contacts. It seems that, in this case, the loosening of the crystals from each other has been the first stage of the transformation of the invaded anorthosites. Afterwards the changes were continued in each crystal separately. Perhaps they were divided along to the cleavage cracks. That the labradorite crystals have been disintegrated by the invading magma is quite certain. Separated from the big plagioclase crystals, by means of veins of the intruding rock, appear small portions of them, and the outer regions of their remains are very irregular, as a consequence of the invasion of the granitic magma. The contours of the sections are formed by concavities occupied by quartz and orthoclase, the former mineral prevailing in quantity. Moreover, small pieces of the anorthosite crystals are scattered throughout the granite-mass.

FROSTERUS[1] has described analogous phenomena from the Sub-Jotnian district of Jaala. It looks as if the metamorphic effects of the invading magma have been of greater importance in the rocks at Räflan, in which region have appeared what are in effect quite new rocks, which are porphyritic, the phenocrysts being the labradorite crystals, and the ground-mass comprising the intruded rock with small fragments of labradorite.

The primary ferro-magnesian minerals have disappeared. Only chloritic accumulations and magnetite are observed. In other cases the metamorphism has been insignificant, or entirely absent, as regards the plagioclases. In those cases the labradorite crystals appear unchanged, and between them occurs a granitic groundmass. There are all the transition-forms between the original anorthosites and the above-mentioned porphyritic rocks.

Sometimes occurs some hornblende in the more metamorphic forms of those rocks, the appearance of which is not always the same. Sometimes clusters of small, irregular magnetite grains are found in the hornblende.

The granites.

The greater part of the region between Omnefjärden and Ullångerfjärden consists of granites of somewhat varying quantitative compositions and textures, but always consisting of roughly the same minerals.

[1] Beskrifning till Bergartskartan S:t Michel. Helsingfors 1902.

They are always reddish rocks. Exceptions to this rule occur, if the granitic bodies contain leptite fragments, when they become grayish, as a consequence of the solution of these rocks. The reddish colour is caused by a pigment, which colours the orthoclase and sometimes even the albite. They consist of *micro-perthite, albite, quartz, hornblende* and, sometimes, *biotite*. The last-mentioned mineral appears to be more typical of the contact regions, hornblende being the ferro-magnesian mineral which is more common. As accessory constituents occur *magnetite, apatite, zircon, titanite*. In some varieties *zircon* and *titanite* appear in relatively large amounts. In some others, almost devoid of dark constituents, the hornblende may be considered as an accessory mineral.

Some of the varieties of this region may be classed with those of the Ulfö-type. They are nearly devoid of ferro-magnesian constituents and are, moreover, distinguished by the typical graphic texture. The different varieties are not distinguished in the map, because they do not occur in large coherent bodies, but in relatively small intrusions, which would render necessary very detailed mapping. Such mapping would have been of interest, of course, but there were more interesting questions to claim the time at my disposal.

Probably all the different varieties are of about the same age. They generally appear in sharp contacts with each other, but they very probably generate from the same magma, and, moreover, their relations to the other rocks, younger as well as older, are of the same nature, for which reason they may be considered as belonging to the same epoch of intrusion.

One of those varieties, containing comparatively large amounts of dark mineral, consists of *micro-perthite, albite, quartz, hornblende*, some *biotite, magnetite, apatite, titanite, zircon*.

The *micro-perthite* is reddish-coloured, but the pigment is very irregularly distributed; there occur crystals which are devoid of it, while others are pigmented only in the outer parts, and others in irregular accumulations and stripes. There occur crystals with dimensions on (010) sections of between 12 and 16 mm.^{2} but others are of less area. The majority of the crystals show sections of over 5 mm.^{2} in the face named. The perthite crystals are anhedral, and include albite as well as quartz.

Albite appears in lesser quantities than perthite, and in smaller crystals; it is seldom that sections over 3 mm.^{2} occur. It is always somewhat turbid, and shows more independent outlines than the perthite, and, in some cases, even than the quartz.

The *quartz* generally appears in rounded crystals. Sections perpendicular to the axis never attain an area greater than 1 mm.^{2} Beyond the crystals with sections of the latter dimensions occur very small grains, as a kind of suture between the large feldspar crystals. Quartz occurs also, together with amphibole and mica, in accumulations of small crystals. Sometimes occurs a graphic implication between this mineral and the

feldspars, but the local developments of that fabric are without significance for the general texture of the rock.

Hornblende. — This mineral does not occur in whole crystals of any importance, but, for the most part, in accumulations, together with chlorite, biotite, magnetite and quartz. The absorption formula is Z = dark green > Y = dark brownish-green > X = brownish-yellow. In the accumulations named, moreover, occur relatively numerous zircon crystals, and some titanite and apatite crystals. This mineral occurs in anhedral crystals.

Biotite occurs in the accumulations in question, and it is the common brown variety. I am inclined to think that this biotite is an alteration-product of the hornblende. It is chloritised, and contains lenticular layers of epidote. The biotite crystals are quite irregular.

The *magnetite* occurs in comparatively large amounts, and probably its proportions approach very near to those of hornblende. The crystals are always anhedral.

Zircon appears in numerous, small, euhedral crystals in the hornblende and magnetite aggregations, and as inclusions in the other minerals.

Titanite nearly always occurs in company with hornblende.

Apatite is observed in the form of inclusions evenly distributed in the rock-mass.

This rock is millimeter-grained and its fabric is seriate homeoid. It appears to me that, in composition, it approaches the quartz-syenites, but it is more acid than they are. This is one of the common varieties. Dikes of an aplitic rock are observed, cutting the above-described granite. The rock consists of *micro-perthite, albite, quartz and biotite,* and, as accessory minerals, appear *fluorite, zircon, apatite* and *magnetite.*

Micro-perthite is the most common constituent, and occurs in anhedral crystals, with sections which, in some cases, attain 2 mm.^{2}, but they are, for the most part, of a less area. It generally contains numerous inclusions of quartz.

Albite appears in much lesser quantities than micro-perthite, and in smaller crystals; is always anhedral. It often contains inclusions of quartz.

Quartz occurs in rounded grains of small dimensions, which exceptionally show sections of 1 mm.^{2} in area, but in most cases they are much smaller. It shows more euhedrality than the feldspars.

The *biotite* appears to have been a common brown variety, which has become altered, and now it shows greenish shades, as a consequence of alteration. It occurs in irregular flakes of varying dimensions. Sometimes the altered biotite crystals contain magnetite between the laminæ. It alters, moreover, to a pleochroic, yellowish-brown mineral of rather strong birefringence, which is probably vermiculite.

Fluorite generally appears scattered among the other minerals, sometimes showing its characteristic bluish-violet colour, but for the most part it is of a white colour.

Zircon and *apatite* appear in very small amounts.

This rock is decimillimeter-grained and its fabric is seriate homeoid.

There are all the transitions between the above-described granite and those of a type, almost devoid of dark minerals and showing graphic fabric, which I call the Ulfö-type, because this is the dominant variety on Ulfö. They will be described in connection with the rocks of this region.

Some Mjällomlandet varieties are relatively rich in dark constituents, but these dark minerals are only aggregations of magnetite, epidote, quartz and some chlorite. These are, perhaps, the results of the alteration of hornblende. In these aggregations occur numerous crystals of zircon and even titanite. Generally the granites in which the femic minerals occur in considerable amounts are devoid of graphic texture, and they are relatively poor in quartz. But in all cases it appears that the quantities of this mineral are greater than in the quartz-syenites.

The boundary between this granite region and the gabbro area is very sinuous, and it is to some extent marked by distinct topographical eatures.

The granites of the contact region.

Omneberget, which borders Omnesjön on its north-eastern shore, consists for the most part of granite. The slope of the hill that limits Omnesjön is very steep, and on its lower part runs the limit between the granites and the gabbro. This limit has about the same direction as the shore, but it is not as regular as it appears in the map At Sebäng it runs nearly due north for a distance of about one kilometer, and then turns southward. It makes a similar abrupt change of direction once more — to the north — and finally it follows the eastern slope of the valley of Färnsvik to the bay of the same name. It may be observed that the granite almost always occupies higher levels than the gabbro. This is observed not only nearly the whole way between the villages of Omne and Färnsviken, but even on the hills to the west of the village of Färnsvik. On the southern slope of Omneberget appear numerous leptite-fragments, included in the gabbro and in the granite. These fragments are partially re-melted and assimilated. The granite becomes grey and porphyritic, the most notable change in its mineral constitution being the appearance of great quantities of biotite. A very similar phenomenon has taken place in the case of the fragments included by the granite on the southern slope of Trollarviksberget,[1] east of Breviken, on the northern coast of Omnefjärden. These, however, are questions that require the help of chemical analysis, besides a petrographical description of the leptites, in order to afford a firm foundation for a discussion of the problems — which I hope to be able to undertake in a subsequent paper. Such inclusions of leptite

[1] Hj. Lundbohm, Berggrunden inom Vesternorrlands län, p. 23. — A. G. Högbom, The igneous Rocks of Ragunda, Alnö, Rödö, and Nordingrå, p. 27,

appear in many places in Nordingrå, but the occurrences in question are perhaps the best exposed.

Along the contact with the gabbro the granite is here and there pyroxene-bearing, and sometimes, as in the hills to the west of Färnsvik, it is very heterogeneous in composition. There appear portions of the rock rich in amphibole, pyroxene and olivine.

On the slopes of Omneberget, along the contacts with the gabbro, occur granitic rocks, which consist of *micro-perthite, plagioclase, quartz, amphibole, mica, pyroxene* and sometimes *fayalite;* as accessory minerals occur *apatite, magnetite, fluorite.* The *micro-perthite* occurs in crystals of irregular shapes, and in some varieties it is implicated with quartz.

The *plagioclase* is somewhat different in composition in the different varieties of these rocks, but generally ranges between oligoclase and oligoclase-andesine. It sometimes occurs in porphyritic crystals. There are, however, varieties containing a relatively large proportion of dark minerals, which only present the same plagioclase as the common granite.

Quartz appears as in the above-described Mjällom granites, but in some varieties it occurs intergrown with micro-perthite and plagioclase.

The *amphibole* is a common hornblende. The absorption formula is Z = dark green > Y = dark brownish-green > X = brownish-yellow. It occurs in independent anhedral crystals, and as an alteration-product of pyroxene. Moreover, it has been observed surrounding the olivine.

The *pyroxene* is a monoclinic variety. The crystals appear in short prisms. Twinning occurs, but not often. The acute bisectrix is positive and the angle of the optic axes appears to be the ordinary one in diopsides and augites. The colour is greenish. This mineral being very altered, I could not decide if it is augite or diopside, but I am inclined to think that it is a diopsidic pyroxene.

Mica is the variety common in these rocks. Z = Y = dark brown > X = yellow. From those varieties with relatively much olivine and pyroxene the mica is almost absent. When these minerals appear in very small quantities, or when they do not occur at all, then biotite is present, in company with common hornblende.

Fayalite appears in most cases in the form of very irregular crystals, which are sometimes rounded. It shows two distinct systems of cleavage, according to (010) and (100). The angle of the optic axes is relatively small, and the acute bisectrix is negative. The dipersion is strong $\rho > \upsilon$. The refraction is high and the double refraction strong. The colour is yellowish-white, and devoid of pleochroism, but it must be remembered that the slice is very thin. This occurrence is identical with that described on p. 43. The alteration is like that in the occurrence mentioned from Ramsta, but here perhaps the iron products are present in greater quantity.

Zircon occurs in rather large amounts, and in subhedral crystals.

Magnetite is observed in subhedral and anhedral crystals, sometimes in rods.

Fluorite and *apatite* are always present, the former in relatively large amounts, sometimes showing the bluish-violet colour, and the latter is in small quantities.

These rocks are of varying granularity, but in most cases they are millimeter-grained. They are frequent from Omnesjön to Färnsviken, along the boundary with the gabbro, and they are of variable composition. In the neighbourhood of Färnsviken there occurs a variety relatively rich in fayalite. The granites in the hills west of Färnsvik are very analogous, but there perhaps they show a more heterogeneous constitution, and there appear in the granitic rock-mass portions rich in fayalite and pyroxene, as if they were assimilated fragments.

Monzonitic rocks.

Another remarkable feature of the boundary-region between the gabbro and the granite is the occurrence of rocks which, in many cases, appear to have a sharp contact with the granitic bodies, but not with the gabbro rocks. It is those rocks that LUNDBOHM expressively called «gabbro-granites». They are rocks whose constitution varies between that of gabbro and that of granite. They are generally such heterogeneous rocks that, within a distance of one meter, their appearance and composition may vary considerably. I believe that the analyses of these rocks will show that they have a monzonitic constitution. In the geological map they are called monzonitic rocks. In employing that denomination I do not allude at all to their genesis. I use the term monzonitic in the same sense as has been given to the word by BRÖGGER. When characterising the monzonites this author says:[1] »Für die saurere Gruppe, welche die herrschenden Gesteinstypen der ganzen Serie umfasst, ist nach meiner Erfahrung die oben citirte Bemerkung von LEMBERG allein zutreffend; er charakterisirte den Monzonit als ein Gestein, «das seiner Constitution nach zwischen Syenit und Diorit zu rechnen ist.» In diesen Worten ist nach meiner Auffassung die wesentliche und charakteristiche Haupteigenthümlichkeit der Gesteine der sauren Gruppe HANSEL's ganz genau und zutreffend angesprochen: Die Monzonite charakterisiren sich eben dadurch, dass sie weder zu den Orthoklas-Gesteinen noch zu den Plagioclas-Gesteinen, sondern zu einer Übergangsgruppe oder Zwischengruppe zwischen beiden gehören, sie sind eben: *Orthoclas-Plagioclas-Gesteine.*» And further he adds: «*Das wirklich charakteristiche bei diesen Gesteinen, nämlich dass sie in der Regel Orthoclas und Plagioklas ungefähr gleich reichlich oder jedenfalls beide reichlich führen, fand dabei gar nicht den zutreffenden Ausdruck.*»

The percentage of SiO_2 in the monzonitic rocks of this district varies between that of the gabbro, which, judging by its mineralogical constitu-

[1] Die Eruptivgesteine des Kristianiagebites. II. Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol, p. 21.

tion, can never be below 48, and that of the granites, which in the most acid varieties attain a percentage of SiO_2 of somewhat above 70. Consequently the analyses will probably show the existence of ademellites, banatites, monzonites, but probably not of those rocks classed in the most basic division of the monzonite series — the kentallenites.

In respect to mineralogical constitution, they contain the minerals existing in the gabbro and granite. In the most acid series of these rocks the orthorhombic pyroxene disappears. The plagioclase becomes more and more sodic with the increase of silica. With regard to the olivines, I have observed that in the gabbros the olivine is rich in iron, but probably it is not of fayalitic constitution. The axial angle was at least larger than in the minerals of the last-named variety. In the most acid of those rocks occurs fayalite, but I do not know if there are intermediate varieties of this mineral — I mean if the iron-percentage of olivine becomes higher as the amount of silica in the rock increases. It will be interesting to investigate if those olivine varieties grade into one another. With the means at my disposal I could not decide the point.

To the south of Salsåker, on BERGLUND's farm, occur gray, quartziferous rocks, some of them of granitic composition. These recall the gray granites of Allsta (see p. 42). A difference between them is that the rocks from Salsåker contain much biotite. BERGLUND's farm lies just on the boundary-line with the Archæan, and for this reason it is natural that the rocks in question should contain numerous fragments of leptite and appear to have partially assimilated them. These rocks contain much fayalite and pyrrhotite.

In the leptites of the contact region, south and south-west of Salsåker, occur numerous small accumulations of the last-named mineral. The constitution of the feldspar of these rocks is variable, but is about the same as in the rocks mentioned as occurring at Allsta.

All these rocks of the boundary-zone will be described in detail and classified in another paper, in connection with a discussion of their chemical constitutions.

The Region North of Ullångerfjärden.

General remarks.

North of Ullångerfjärden, occupying the eastern part of the parish of Vibyggerå and the south-eastern parts of the parishes of Nätra and Själevad, appear, for the most part, the same rocks as those described in connection with the parish of Nordingrå. For that reason I shall briefly record some peculiarities in their appearance and composition.

The gabbro extends in a narrow band, from the neighbourhood of Knäppa, on the northern shore of Ullångerfjärden, nearly to the cattle-sheds of Berg. This band is broken in the region west of Gällstasjön, where the granite is in contact with the Archæan. The gabbro appears here and there in the region north of Magdbäcken, in the parish of Nätra, but these occurrences are very slight and sporadic, for which reason they are not shown on the map. This gabbro is quite identical with the gabbro of Nordingrå.

In the region of the village of Sätra, west of the northern region of Dockstafjärden, appears an anorthositic rock, which I represent in the same way as the anorthosites from the parish of Nordingrå.

Monzonitic rocks occur in the vicinity of Skofed, west of Herresta, and especially in the region between Magdbäcken and Skulesjön, bordering the granitic masses.

The granites occupy the greater part of this region. They are generally of the same constitution as those of Nordingrå.

In the region to the south of Skulesjön the granite is probably in contact with the Archæan, but the contact line is hidden. In the region south of Näske there is a granitic region, quite surrounded by diabase. Between Näskefjärden and Nätrafjärden the granite is separated from the Archæan by a region of diabase. To the north-east of Nätrafjärden the granites appear directly in contact with leptites.

The Jotnian quartzitic sandstone appears only in the islands in the eastern part of the district. On Ulfön, at the foot of Hamnberget, occurs a sandstone inclusion in the diabase. To the north of Ulfön, in the north-

eastern part of Skrubban, as well as in Trysundaholmen and Trysundaön, the sandstone occurs in the same way as it does in Nordingrå and Ramsta. It is protected by a diabase covering, and in Trysundaön it lies over a granite-arkose.

The Post-Jotnian rocks appear in the region of Näskefjärden, and in the islands between Ulfön, in the south, and Råskärsön, in the north.

The granites.

The small, granitic region inmediately to the east of the village of Knäppa consists of a rock which has a composition recalling that of the Allsta granite. It consists of *micro-perthite, plagioclase, quartz, fayalite, pyroxene, hornblende* and *biotite,* as essential minerals, and *magnetite, apatite, zircon* and *fluorite* as accessory constituents.

The *micro-perthite* almost always appears in graphic intergrowth with quartz. There occur, moreover, some crystals which appear to consist only of orthoclase. The sections of micro-perthite and orthoclase are, on an average, between 1 and 2 mm^2.

Plagioclase is generally zonally built, and its composition ranges from sodic andesines and oligoclase-andesines to oligoclase-albites and albite. There occur porphyritic crystals of this mineral, which sometimes have an area on (010) of about 9 $mm.^2$ The non-porphyritic crystals show sections as large as those of micro-perthite. They are, in many cases, much kaolinised, and here and there in their neighbourhood appear fan-shaped crystals and accumulations of prehnite. The proportion of plagioclase in this rock is variable; sometimes it is rather large, and then the rock ought to be classed among the monzonitic rocks.

Quartz. — The largest quartz sections seldom attain an area of 1 mm^2. This mineral occurs in independent crystals and in graphic intergrowth with micro-perthite. It happens that quartz appears implicated with plagioclase in the outer parts of the crystals of this mineral, which are always anhedral.

Fayalite occurs about in the same way as in the other fayalite-bearing rocks, described above. The crystals are anhedral, their sections in rare instances attaining dimensions of nearly 1 $mm.^2$ But in most cases they are below this figure. The fayalite shows a strong dispersion $\rho > \upsilon$, and the sign is negative. The axial angle appears to be the one usual in this mineral. The colour is yellowish-white, and pleochroism is scarcely noticeable. It is generally surrounded by hornblende, and sometimes even by biotite. The alteration-products are, for the most part, serpentine and magnetite.

Pyroxene occurs sometimes, but in much lesser amounts than the above-mentioned mineral. It is a diopsidic variety, and is generally altered to hornblende.

The *hornblende* is a greenish-brown variety. Sometimes it shows, in vertical sections, an area of about 3 mm.^{2}, but in most cases they are much smaller. The crystals are always very irregular and some of the largest ones contain numerous inclusions, especially of quartz, having in rare instances a poikilitic appearance. The absorption formula of this hornblende is Z = dark olive green > Y = dark brownish-green > X brownish-yellow. The quantity of hornblende is very variable. I have studied slices almost devoid of it, but this mineral is generally represented in the rock.

Biotite. This mineral occurs in greater amount than hornblende. Its absorption and pleochroism is Z = Y = dark brown and X = yellow. It appears in irregular flakes, and its sections sometimes attain 1 mm^2, but in most cases they have smaller dimensions. All the varieties of the rocks of this limited region contain biotite in greater or less amount. The presence of biotite in quantities of some importance is typical of the granites of the contact regions.

Magnetite occurs as a primary constituent, and as an alteration product of fayalite. In the first case it appears in rods of small dimensions, and it has been one of the first minerals to crystallise. In the second case it appears in irregular and rather large grains.

Apatite, zircon, and *fluorite* occur in small quantities.

This rock is medium-grained, its granularity being between decimillimeter-grained and millimeter-grained. Its fabric is seriate porphyroid.

The small region to the north-east of Sjöland quay consists of a somewhat porphyritic, hornblende-bearing granite.

It consists of *micro-perthite, plagioclase, quartz, biotite* and *hornblende.* The accessory minerals are the same as in the rock east of Knäppa.

The *micro-perthite* occurs in porphyritic crystals, which show sections of 4 mm^2, and in crystals of less size, whose sections are below 1 mm.^{2} The crystals are always anhedral.

The *plagioclase* is also crystallised in crystals which cover a wide range, showing transitions between crystals of 4 mm.^{2} in section and such small ones as have sections of less than 0,50 mm.^{2} Their composition ranges between oligoclase-andesine and albite. The crystals are anhedral.

Quartz appears in rounded, porphyritic grains, with sections of 5 mm.^{2} in area, and in very minute grains, intermediate sizes existing between the extremes.

The *hornblende* is of the variety usual in all these rocks. It occurs in greater quantities than *biotite.* The crystals are always irregular. The relatively large porphyritic crystals are sometimes graphically intergrown in the peripherical regions. The feldspars are implicated with quartz, and the porphyritic quartz crystals with orthoclase. But, for the most part, the porphyritic crystals are surrounded by a micro-granitic groundmass.

The fabric is seriate intersertal.

The granite of Fäberget. — At Fäberget (the highest hill in the neighbourhood of Sjöland, lying to the east of that village) occurs a porphyritic granitic. The porphyritic crystals appear to be of oligoclase-andesine. In the central part of one of them I observed an un-twinned feldspar with lower refringence, which is probably orthoclase. They are intergrown with each other, and in the orthoclase there are included small anhedral plagioclase crystals. The porphyritic crystals are surrounded by a graphic implication of micro-perthite and quartz, and some of them show sections of more than 100 mm.^{2}

Albite has also separated in independent crystals, which show sections of about 4 mm.^{2}

The granularity of this rock is between millimeter- and centimeter-grained. The fabric is seriate porphyritic, and graphic.

The dark constituents of this rock are chloritic accumulations and magnetite, and the accessory constituents are the same as in the other granitic rocks, described above.

The Käxed-type. — In the surroundings of Norrfjärden (in the region neighbouring on Käxed and Värns), and even in some regions of Mjällom, in Nordingrå, occurs a coarse-grained type, which in composition approaches very near to the quartz syenites. It is a beautiful rock in various shades of red, and comparatively rich in ferro-magnesian minerals. The rock consists of *micro-perthite, plagioclase, quartz, hornblende, pyroxene, fayalite, biotite,* as essential constituents, and *zircon, magnetite* and *apatite,* as accessory minerals.

The *micro-perthite* occurs in large crystals, with sections which attain an area of 40 mm.^{2} The orthoclasic parts of the crystals are red-pigmented. The crystals are always anhedral and include the other minerals. The micro-perthite is the mineral which occurs in greatest amount.

Plagioclase. This mineral occurs, for the most part, in anhedral crystals, showing sections of about 1 or 2 mm.^{2} They are zonally built, their composition ranging from oligoclase-andesine Ab_{69} An_{31} to albite, but sometimes they occur showing a kind of intergrowth with each other. They sometimes occur included in the large micro-perthite crystals, but generally they form accumulations in the spaces between those crystals.

The *quartz* generally occurs in rounded grains, the sections of which attain dimensions of 4 mm.^{2} Sometimes they are nearly subhedral. It occurs in very irregular grains included in the perthite crystals. It happens that these grains have the same orientation. But, for the most part, the quartz crystals occur in the interspaces between the large micro-perthite crystals. Graphic implication between this mineral and perthite or plagioclase is uncommon, but it does occur, though not well developed.

Hornblende. Its absorption formula is Z = very dark green > Y = dark brownish-green > X = brownish-yellow. This mineral appears as a secondary product of the pyroxene, and as independent crystals, probably

primary, but it is difficult to distinguish them. Sometimes appears a lighter green variety, but there are transition-forms between them. Hornblende occurs in quite shapeless crystals.

The *pyroxene* looks as though it were a diopsidic variety, and probably it is rich in iron. I could not detect any dispersion in the A-axis, but there is some dispersion in the A'-axis. Complete extinction is obtained in sections parallel to (010). $\gamma - \alpha$ is between 0,028 and 0,029. This was measured by observing the interference colours of a section of quartz, cut parallel to the axis, and of an adjacent section of pyroxene, cut perpendicular to Y.

The difference of path in the quartz, and in the pyroxene were measured by means of an ocular with quartz wedge.

In slices of the thickness of 0,031 mm. the pyroxene is pleochroitic. Z = clear brownish-green, Y = clear green, X = brownish-green. The axial angle appears to be as in diopside, and the sign is positive. This mineral almost always occurs surrounded by, or altered into, hornblende. The crystals are anhedral, somewhat elongated in the direction of the c-axis. In most cases the sections have an area of less than 1 mm.^{2}

Fayalite. — This mineral is recognized by its high refringence and strong birefringence; by the strong dispersion $\rho > \upsilon$, and by the optic angle, which is much less than in chrysolite; and, morover, by the positive sign. The colour is yellowish-white. Besides these properties the alteration-products are typical. The crystals are always anhedral, somewhat rounded, and generally surrounded by amphibole. The cleavage parallel to (010) is very distinct. It occurs in less amount than pyroxene, and sometimes includes small, rounded pyroxene grains.

Biotite occurs in small quantities, and sometimes it is absent altogether. It is the common brown variety. Z = Y = dark brown, and X = yellow. It is sometimes altered into a greenish variety, and into chlorite.

Magnetite occurs as a primary constituent, and as an alteration-product of fayalite. In the last case it appears in irregular grains, but when primary more regular outlines are shown, and it occurs as inclusions in the other minerals, excepting apatite. I have also observed it included in zircon. The crystals are always very small.

Zircon is common in these rocks, and appears in well-faced crystals. The same may be said of *apatite.*

It may be added that this rock is centimeter-grained. The fabric is seriate intersertal. The graphic intergrowths occurring in it are too insignificant to characterize the rock. What is characteristic of the texture of this rock is the fact that even early crystallised minerals fill the interstices between the large micro-perthite crystals.

This is an interesting rock, and it would be tempting to make comparisons with other rocks of the same kind already described, but I think that, without analysis, such comparisons might be misleading.

In the same regions there occur more quartziferous varieties, which sometimes contain plagioclase in large proportions, and are real monzonites of the acid group. In some of them the plagioclases attain dimensions as great as those of the *micro-perthite*.

In the region between Norrfjärden and Näskefjärden, besides the varieties of Norrfjärden, appear some of the Ulfö-type.

On Elgön the most common varieties are those of the last-named type. There occur two granites in sharp contact with each other. One of them is of a pronounced reddish colour, and in texture, as well as in constitution, may be classed together with the rock from Norrtaskberget (N. Ulfön). The other appears to be somewhat younger, and of nearly the same composition, but it is of a paler colour, and is perhaps composed of somewhat less dark minerals. In both, but more specially in the paler variety, the graphic fabric is dominant. Both are somewhat porphyritic.

On the east coast of the island there occur streaks in the granite, which is very like the paler variety mentioned above.

The streaks consist of a dark, reddish rock, which contains fragmentary inclusions of a black aphanitic rock.

The rock of the streaks is composed of the same minerals as the granite in which the streaks are found, with the difference that the minerals, *pyroxene, fayalite* and *hornblende* occur in great amount. The fragmentary inclusions consist of hornblende, biotite, magnetite, and feldspars, the ferro-magnesian minerals predominating. The magnetite occurs in those inclusions as an essential constituent.

I secured some pieces of the granite from a spot situated at some meters from the streaks, and in the slices I studied I did not observe any traces of fayalite. In the kernel of a hornblende crystal I could see some relics of pyroxene. The granite consists of *micro-perthite, albite, quartz, hornblende, mica, magnetite, zircon, apatite* and *fluorite*. The rock is a rather coarse-grained variety of granite, and there is nothing noteworthy about its minerals, except for the biotite, which presents very uncommon greenish-yellow shades of colour, as a consequence of alteration. The fabric is seriate intersertal, but the graphic fabric plays an important rôle too.

On Strängön there occurs a coarse-grained variety, with a granularity about the same as that of the Käxed type, but it is much more acid. In this rock the femic minerals are hornblende and biotite, and the plagioclase, which occurs in rather great quantities, is albite.

All these granites are cut by gray and reddish-coloured aplitic dikes. These are always biotite-aplites, and consist of *albite, micro-perthite, quartz,* and *biotite,* as essential minerals, and *zircon, fluorite, apatite* and *magnetite* as accessory constituents. Sometimes these aplitic rocks are somewhat porphyritic. The micro-perthite shows a tendency to crystallise in crystals of larger size than those of the other minerals. Here and there the quartz appears in graphic implication with micro-perthite, and in some varieties it may be said that this texture characterizes the rock. The biotite in

all these rocks has been one of the first minerals to crystallise, appearing with well-defined contours, and cutting the quartz and the feldspars. Basic dike-rocks have never been observed, excepting those originating from the Post-Jotnian diabase. In the islands just to the south of the boundary of the district, especially in Normanö, occur some porphyritic granites, containing relatively great amounts of pyroxene and fayalite; zircon appears also in comparatively large quantities, and sometimes the sections attain dimensions of $(0{,}50 \times 0{,}10)$ mm.^{2} The porphyritic crystals are of micro-perthite, and around them predominates a graphic implication between micro-perthite and quartz. The hornblende in some of these rocks includes numerous crystals — especially of quartz — forming a kind of poikilitic fabric, but the inclusions are too large for the fabric to be a real poikilitic one.

The contacts of the granites with the leptites. In the northern part of the district, between Nätrafjärden and Guldvikfjärden, the granitic masses come into contact with leptites.

These contacts can be observed in many places, and are of special interest, because they give an idea of the conditions of the granitic magmas during their solidification. Their nature is better understood when they are compared with the contacts of the Post-Jotnian rocks, the contacts of which with the Jotnian or Sub-Jotnian are always like those of rocks which have been rather rapidly chilled. They show aphanitic and even vitrous facies at the contacts, and the boundary between them and the country-rock is very sharp. The country-rock, in these cases, has been relatively cold, and probably the solidification of those magmas has taken place at a comparatively small distance below the surface, under a covering of rocks of slight thickness. The contacts of the granites with the Archæan rocks do not show such characteristics. See Plate XI. In the above-named region, between Nätrafjärden and Guldvikfjärden, at the contacts, they are porphyritic, and there is not a sharp line of division between the granites and the leptites; there is a transition zone. This zone appears to consist of a mixed rock. This may be called impregnation of the older rock by the molten solution, and although it may be said that the country-rock was not melted, yet there should seem to be indications that it was. At least one circumstance may be considered as certain — that the older rocks were at a very high temperature. The fact may be taken into consideration that there is not only a textural change in the leptites, but also a chemical one. The same occurs in other contact regions in Nätra and Vibyggerå, where the granites show new textural and chemical facies, as a consequence of assimilation.

The Anorthositic Rock of Sätra.

In the vicinity of the village of Sätra occurs an anorthositic rock. It consists of *plagioclase, orthoclase, quartz, diallage, orthorhombic pyroxene, biotite, hornblende, magnetite* and *apatite. Olivine* has been not observed.

Plagioclase. — On cleavage flakes parallel to (010) the extinction angle was $-23°$, and, consequently, the plagioclase is a labradorite, Ab_{39} An_{61}. The plagioclases are white and very little altered. As in the plagioclase of the gabbro, there occur in the plagioclase of this rock microscopical inclusions of an opaque mineral. The crystals of the plagioclase are for the most part tabular, and flattened according to (010). Their forms are anhedral and subhedral. The size of the crystals varies. Sections of 50 mm.^{2} are not uncommon.

Orthoclase and *quartz* appear in the same way as in the gabbro of Nordingrå. They have been the last minerals to crystallise.

The *diallage* and the *orthorombic pyroxene* occur in the same way as in the gabbro. In the former the inclusions appear to be more numerous, and the sub-metallic lustre is much more pronounced. The same mineral is, moreover, somewhat pleochroitic in reddish-brown (with a somewhat violet shade) and greenish colours.

Hornblende occurs only in small quantities, but *biotite* appears in rather large amounts, generally in company with magnetite and surrounding it.

Magnetite occurs in the form of irregular crystals, but also in rods included in the above-named minerals, and *apatite* appears in anhedral crystals.

The fabric is seriate intersertal. The spaces between the large plagioclases are filled with relatively small crystals of plagioclase and the other minerals mentioned. The rock in these spaces is millimeter-grained.

This rock, in constitution as well as in texture, is an intermediate form between the gabbro and the anorthosites of Nordingrå.

The monzonitic rocks.

In the western region of Dockstafjärden, in the neighbourhood of Skofed and Sjöland, occur monzonitic rocks. What has been said about the monzonitic rocks of Nordingrå may be reiterated here. The Skofed rock is very rich in hornblende and biotite. Pyroxene occurs very altered into hornblende, and surrounded by it; its crystals are elongated in the direction of to the c-axis. Apatite occurs in very numerous euhedral and subhedral crystals.

These rocks occur, here and there, nearly the whole way from Skofed to Gällstasjön. From Magdbäcken to the region of the cattle-sheds of Nyland[1] the granitic masses are bordered by a belt of analogous varieties. In the neighbourhood of the cattle-sheds of Nyland they are fine-grained and porphyritic, and, for the most part, they are rocks rich in hornblende. Especially in a little hill to the north-west of the cattle-sheds it is possible to observe their great diversity. Generally it is difficult to find a spot of even a few square meters where the rock presents the same appearance.

[1] Hj. Lundbohm, Berggrunden inom Vesternorrlands län, p. 24.

The monzonitic region of Alviken.

In the vicinity of Alviken (south of Köpmanholmen), on the northern slope of Vårdkasberget, occurs a region of monzonitic rocks. Their constitution varies between that of diabase and that of granite.

The granitic rock of the northern slope of Vårdkasberget is a graphophyre of the Ulfö-type, consisting principally of *micro-perthite,* in graphic intergrowth with quartz. It seems that the albite is present in less amount than in the Ulfö rock (from Norrtaskberget).

The *orthoclase,* which is very strongly red-pigmented and nearly opaque, sometimes appears as if it were free from albite implications, but perhaps it is crypto-perthite. There are only traces of ferro-magnesian minerals, and they are in the form of some small chloritic accumulations.

Between the region of this granite and the diabase region appear all the transitions between these two rocks. These monzonitic rocks are Post-Jotnian. The diabase is a variety rich in olivine. Monzonitic rocks analogous to those of Alviken will be described in the chapter on Ulfön.

The islands to the north-east of Ulfön.

Between the entrance to Örnsköldsvikstjärden and Ulfön there is a row of small islands, whose rocks consist, for the most part, of diabase and granite.

The granites are either one of the varieties already described, or of the Ulfö-type. The diabase with its varieties (which will be described in the following pages) occurs in Ulföarne, where the contact relations between these two rocks, which are very interesting, are best illustrated. I have followed these contacts in each of the small islands, and everywhere I observed the same features as in Ulföarne.

Trysundaön.

The most interesting of these islands, from the geological point of view, is Trysundaön, the geological features of which have been exactly described by LUNDBOHM.[1] See Plate XII, Fig. 1.

In the island occur granites (Sub-Jotnian), arkose and quartzitic sandstone (Jotnian), and diabase (Post-Jotnian). The granite is about the same as that on Ulfön. It occurs in the region included between Bockviken, Björnviken, and the fishing harbour. Consequently, it is west and north of Kappelsberget that the granite occurs. The granite is covered by a granitic arkose, and these are connected with each other by transition-rocks. North of Kappelsberget, near the shore, the granite is quite normal. It is a very fresh rock. Going to the south, in the direction of the above-mentioned hill, it becomes altered. At about 8 or 10 m. above the sea the granite is already arkose-like, and at the altitude of the track which leads from the fishing-harbour to Björnviken it is a real arkose. The ferro-magnesian minerals have disappeared, the feldspars are very altered, and there occur dark-coloured streaks, which consist of ferruginous particles. At about 17 m. above the sea the streaks become broad bands, and in this way

[1] Berggrunden inom Vesternorrlands län, p. 21.

the arkose is built of alternate bands, or layers, of light granitic material and dark, fine-grained material, rich in ferruginous particles. See Plate III.

The light bands consist principally of quartz and altered, red-pigmented orthoclase. The material appears to lie *in situ*, as it did in the igneous rock, the orthoclase occurs in graphic implication with quartz, and it is nothing else but its very advanced decomposition that distinguishes this rock from the granite some meters below. Sometimes in these granitic bands occur ferruginous particles, accumulated in streaks. Their direction conforms in general to the planes of sedimentation of the sandstone. It happens that they form dipping surfaces, enveloping the large quartz or feldspar grains; but sometimes, when the quartz grains are too large, the upper layers lie over and along the upper surfaces of the grains, but those which succeed below are somewhat bent upward terminating in the surface of the grain, without enveloping it, and the lowest layers may be nearly horizontal.

The ferruginous material is in part reddish and in part black. The reddish material is cloudy and resembles a pigment. The black material consists of accumulations of very small, rounded and, for the most part, equidimensional grains — so perhaps it is magnetite. These ferruginous bands do not consist only of the above-mentioned particles, but also of small quartz grains, and very minute flakes of a colourless, micaceous mineral, which is probably muscovite. In the highest regions of the arkose the light or granitic layers contain very much white mica.

Scattered in the arkose occur quartz concretions. They are sometimes rounded, but they appear in varying shapes and sizes, their sections being sometimes nearly square, with somewhat rounded corners. Orthoclase grains appear sprinkled in the more ferruginous layers. The quartz concretions, as well as the orthoclase crystals referred to, give to the rock a porphyritic texture. The texture of the rock, especially of the upper layers, is, moreover, banded. The thickness of the bands varies, and may range from something quite microscopic to something over 20 cm. See Plate III.

In this locality the contact of this rock with the overlying Jotnian quartzitic sandstone is hidden by a talus of diabase blocks, but immediately to the north of the fishermen's huts, at about 50 m. to the west of the escarpment of Kappelsberget, it is possible to observe these rocks in contact with each other.

The thickness of the arkose can not be stated with certainty. I consider it probable that, in the northern region of Kappelsberget, the difference in level between the upper and the lower layers of the arkose is about 20 m. LUNDBOHM, in his description of Trysundaön cited above, writes the following about the arkose: »The lower layers of the indubitably sandstone formation consist of a dark violet, tolerably loose slate, which lies over a remarkable rock, which, macroscopically, has a granitic appearance, but which, in several places, is evidently stratified, owing to the

occurrence of slate-like layers, composed of lamellæ of about the same nature as the overlying slate. Besides, not seldom it contains balls of white quartz, of the same kind as those occurring in the conglomerate of the sandstone formation. The quartz balls sometimes appear to be distributed in conformity with the planes of stratification. The thickness of this rock may be estimated at 5 to 6 m. Under it has been observed granite of tolerably normal appearance.

When examining the profiles in Trysundaön and Räflan one comes, at first, to a positive conclusion that the granite is younger than the sandstone, and that it has penetrated between the layers of the sandstone and taken up a part of the constituents of the sandstone. The appearance of the granite (which is generally normal), the occurrence in it of small pieces of slate which resemble fragments, a very striking unconformity (which is probably only apparent) between the contact line and the sandstone layers, and even other circumstances, appear to support that supposition.

To decide this question numerous slices of the granite with inclosed pieces of slate were made, as well as slices of the sandstone and the slate. Not seldom the granite showed indications of clastic structure, which had never been observed in the normal varieties of this rock. In some slices it was found that fine slate-lamellæ enclosed small, rounded grains of granite and — what is more conclusive — in the violet slate of Trysundaön were found small angular and rounded fragments of quartz and feldspar in graphic implication, which is typical of the granite; whence it must be considered that the granite has at least contributed a part of the material which builds the slate. But real pebbles of granite were never found in the sandstone. The principal result of the examination was the conclusion that probably a normal covering occurs, or that the slate and sandstone have been deposited over a somewhat eroded and cracked granite surface.»

I believe that the slate which, according to LUNDBOHM, contains the granitic fragments, showing feldspar and quartz in graphic intergrowth, does not belong to the sandstone formation, but is one of those dark bands of the arkose. In slices of slate and sandstone from several localities I never found anything like what LUNDBOHM described; but in the slate-like bands of the upper regions of the arkose occurs something of the sort.

In respect to the general geological relations between the arkoses, the sandstone formation, and the Sub-Jotnian rocks, I refer to the remarks on p. 40 of this paper.

The difference of level between the upper and the lower layers of the sandstone in Kappelsberget is about 20 m., and that between the upper sandstone-layers and the highest part of the overlying diabase is about 40 m. The diabase covers and penetrates the sandstone in the same way as in the other analogous localities of this district.

The western coast of the island is bordered by sandstone, the bottom layers of which lie below the surface of the sea. This region appears to

be sunk[1] in relation to Kappelsberget. It seems that there is a fault along the western shore of Bockviken, running in a nearly N—S direction. To the south of the last-named bay the granite (arkose-like) occurs at higher levels than the diabase.

Trysundaholmen and Skrubban.

On the northern coast of Trysundaholmen occurs sandstone, and the same is the case along the coast of the north-western corner of Skrubban, the island about one kilometer to the south-west of Trysunda. The west and north coasts of Skrubban are very steep. The island consists chiefly of diabase only, the sandstone only appearing in the places named. It appears that the diabase surface conforms to the surface of the sandstone, into which it has been intruded.

The way in which the diabase has invaded the sandstone is well illustrated at the northern end of Skrubban. A part of the sandstone appears above the water with normal dip, and, as it seems, quite undisturbed, but inmediately above occur sandstone layers lifted up in quite opposite directions. See LUNDBOHM's sketch on p. 22 of the work cited, and also Plates II and IV.

[1] See the profile published by LUNDBOHM on p. 20 of his work, and the explanation on p. 21.

Ulfön.

As a gigantic breakwater at the entrance of Ullångerfjärden extend Ulföarne (the Ulf-islands), in a nearly N—S direction. There are two islands: N. Ulfön and S. Ulfön, separated by a narrow sound, Ulfösundet; but, perhaps because only the northern island is inhabited the whole year, the natives generally use the shorter name, Ulfön, for both islands, thus, by Ulfön, meaning N. Ulfön, in a more strict signification. These islands consist chiefly of a Sub-Jotnian granite and of Post-Jotnian diabase. The granite occupies the western half of the northern island, and a part of the eastern and a part of the western coast-regions in the southern island. The diabase occurs in the eastern half of N. Ulfön, and in the southern region and in the central part of the northern region of S. Ulfön.

The Sub-Jotnian rocks.

The granite.

In reality there occur two varieties of granite: one almost devoid of ferro-magnesian minerals and more fine-grained, and one which I call the Ulfö-type (containing hornblende) which is the type that, in chemical constitution as well as in texture, comes nearer the rapakivi rocks. This variety it is which has the largest extension. The difference between them is very small, and consists in the amount of ferro-magnesian minerals. I have taken the Norrtaskberget rock as a type, because not only its composition, but even its texture is the most common. It will be remembered that this granite is wide-spread, occurring not only in the neighbouring islets and islands, but even in the granitic regions of Nätra, Vibyggerå and Nordingrå, as has been stated above.

It is a brick-red, porphyritic rock, showing parallelepipedic crystals of micro-perthite, with sections which sometimes attain (15×10) mm^2, imbedded in a kind of groundmass of graphically implicated quartz and microperthite.

From the groundmass may be separated rather large, rounded quartz crystals, of about two, sometimes three, millimeters in diameter, which give to the rock a quartz-porphyritic appearance. The rock consists of *quartz, micro perthite, albite, hornblende, chloritic accumulations, magnetite, titanite, fluorite, zircon.*

The *quartz* occurs in subhedral crystals of about two millimeters in diameter, and in smaller grains of irregular shapes.

The larger, subhedral quartz crystals may be considered as phenocrysts. They resemble equidimensional hexagonal bipyramids.

There are cases in which the prismatic faces are also developed. Most of the quartz is associated with micro-perthite in graphic intergrowth.

The *micro-perthite* occurs as rather large, phenocrystic crystals, and as a kind of groundmass, in both cases implicated with quartz.

The largest crystals are about 15 mm. in length, and they are not at all euhedral or homogeneous. Even a hasty inspection shows that they have numerous quartz-inclusions.

They have not well-defined contours, and in their peripheric regions, and sometimes in their central parts, show a graphic implication. This implication may be quite local, with very little extension outward, and surrounded by an analogous implication independent of it; but it may happen that the large micro-perthite individual is enveloped by an implication of considerable extension and partly composed of ramifications from the individual. So the micro-perthite of the surrounding implication belongs to the same crystal as the larger micro-perthite individual.

It is the orthoclase that gives the red colour to the rock, as a consequence of its characteristic pigmentation. The pigment is very irregularly distributed. In different parts of the rock we can observe variations in the colour; and even in the same orthoclase crystal this irregularity in the accumulation of pigment is very perceptible. Sometimes the pigmentation is so dense that the orthoclase becomes nearly opaque.

The *plagioclase* is observed implicated with the orthoclase and quartz, and in independent crystals, generally subhedral. The extinction angles on (010) are about $+ 18^\circ$ or $+ 19^\circ$, so that it is an albite. It is always turbid, as a consequence of very small interpositions, and occurs in small crystals, with sections which attain an area of 2 mm.^{2}

The *magnetite* occurs in irregular crystals, about 1 mm. in diameter, and seems to have been one of the first minerals to crystallise.

The *titanite* appears in subhedral and anhedral crystals, of about 0,5 mm. in diameter.

Fluorite occurs filling up small (1 mm. in d.) irregular-shaped cavities. Its colour is generally white, but sometimes it is violet-blue.

Zircon occurs in small amounts, crystallising in beautiful euhedral prisms, elongated parallel to c and terminated by pyramidal faces. It has

been the earliest mineral to crystallize in this rock. The colour is yellowish-white. In a crystal taken at random:

Dimension in a direction perpendicular to c = 0,09 mm.
» » » » parallel to . . . c = 0,27 mm.

The *chloritic accumulations* are mixed with magnetite, and are probably the end-products of the alteration of common hornblende. In a slice of the rock from N. Vårdkasberget, immediately to the east of Norrbyn, I have observed all the transitions between a brownish-green, unaltered common hornblende and the above-mentioned chloritic accumulations.

The *hornblende* is of the common, brownish-green variety, mentioned when describing the other granites, and occurs in small amounts.

The quartz and micro-perthite, whose forms in general follow crystallographic faces, very often show sacciform inclusions. See Plate VI, Fig. 2. These inclusions are built up of implicated quartz and orthoclase, and of albite. Sometimes it is observed that the albite of the perthite is partially surrounded by quartz. This quartz is quite without crystallographic outlines.

Rapakivi texture — plagioclase surrounding orthoclase — has not been observed in the Norrtaskberget rock. That texture does occur in small, rounded, or in parallelepipedic crystals, but in other regions of the granitic body.

Thus, in this rock we find that there are porphyritic crystals of orthoclase and of quartz. These porphyritic crystals are subhedral. In some regions they show, well-developed crystal faces, but in other regions of the same crystal the regularity in outline is lost. Moreover, they enclose not only the earliest crystallised minerals, but also small portions of the groundmass and of the other minerals, which will have been crystallised late.

I have pointed out before that the feldspar of the implicated groundmass has sometimes the same orientation as an adjacent porphyritic crystal, and that sometimes ramifications from the big crystal take part in the building of the groundmass. The same is the case with the porphyritic quartz crystals which do not only form part of the groundmass by means of ramifications, but also have the same orientation as the small grains of the graphic groundmass. See Plate VI, Fig. 2.

Taking all these circumstances into consideration, it looks as if the crystallisation of the groundmass was, at least in some cases, simultaneous with that of the phenocrysts which it surrounds.

As in the normal varieties of granites, we find that in this rock $CaO + MgO < K_2O + Na_2O$ and $Al_2O_3 > K_2O + NaO$. The difference between the alumina and the amount of the alkalies is tolerably slight, and for this reason it may be considered to be a sub-alkali-rock. The amount of iron is relatively large, as in analogous rocks when they are amphibole or pyroxene-bearing.

TABLE I.

Liparose-Alascose[1] (Granite of the Ulfö type). Norrtaskberget, N. Ulfön.
(Analyst, N. SAHLBOM.)

	Per cent	Mol.	Mol. per cent
H_2O	0,18		
H_2O	0,28		
SiO_2	73,77	1,2295	80,93
TiO_2	0,22	0,0027	0,18
Al_2O_3	12,68	0,1243	8,18
Fe_2O_3	2,40	0,0150	—
FeO	0,45	0,0062	2,38
MnO	0,01	0,0001	0,01
CaO	0,46	0,0082	0,54
MgO	0,33	0,0082	0,54
K_2O	5,58	0,0594	3,91
Na_2O	3,14	0,0506	3,33
P_2O_5	traces	—	—
S	0,07	0,0022	—
Fl	0,21	0,0055	—
BaO	0,00	—	—
ZrO_2	0,00	—	—
	99,78		
O for Fl_2	0,09		
	99,69		

Quantitative Classification.

Formula	Mol.	WT.		Norm.				
SiO_2	5587 ×	60 =	Quartz	= 33,522	Q	33,522		
$K_2O . Al_2O_3 . 6SiO_2$	594 ×	556 =	Orthoclase	= 33,026				
$Na_2O . Al_2O_3 . 6SiO_2$	506 ×	524 =	Albite	= 26,514	F	61,041	Sal	95,471
$CaO . Al_2O_3 . 2SiO_2$	54 ×	278 =	Anorthite	= 1,501				
Al_2O_3	89 ×	102 =	Corundum	= 0,908	C	0,908		
MgO		=	Mg O	= 0,330				
$FeO . Fe_2O_3$	25 ×	232 =	Magnetite	= 0,580				
Fe_2O_3	125 ×	160 =	Hematite	= 2,000	M	3,320		
$FeO . TiO_2$	27 ×	152 =	Ilmenite	= 0,410			Fem	3,802
CaF_2	28 ×	78 =	Fluorite	= 0,218				
FeS_2	22 ×	120 =	Pyrite	= 0,264	A	0,482		
			H_2O	= 0,460				

$$\underset{\text{Persalane}}{\frac{Sal}{Fem}} = \frac{95,47}{3,80} > \frac{7}{1}\ (\text{Class I});\quad \underset{\substack{\text{Britannare}\\\text{Columbare}}}{\frac{Q}{F}} = \frac{33,52}{61,04} = 0,55 < \frac{3}{5} > \frac{1}{7}\ (\text{Order 4});\quad \underset{\text{Liparase Alaskase}}{\frac{K_2O + Na_2O}{CaO}} = \frac{1100}{82} > \frac{7}{1}\ (\text{Rang I});\quad \underset{\substack{\text{Liparose}\\\text{Alaskose}}}{\frac{K_2O}{Na_2O}} = \frac{594}{506} < \frac{5}{3} > \frac{3}{5}\ (\text{Subrang 3})$$

Osann's Classification.

s = 81,11	n = 4,60			
A = 7,24	a = 13,62	k = 1,70		
C = 0,94	c = 1,78			
F = 2,45	f = 4,60			

[1] The sample has been dried at 106°. H_2O = 0,18 %.

Not only from a qualitative point of view, but even quantitatively, this rock is very like the granite of Rödö, described by HOLMQUIST.[1] The Ulfö-type is, however, somewhat richer in alkalies and poorer in alumina. In respect to comparisons with the Finnish rapakivi-rocks I refer to the above-mentioned work of HOLMQUIST.

Aplites are the only dike-rocks occurring in association with the granite, and are like those described in connection with the other granitic regions.

The Post-Jotnian Rocks.

The Post-Jotnian rocks, the occurrences of which have been mentioned in the foregoing pages, are perhaps the most interesting rocks of the district. The range of variation in their mineralogical, as well as in their chemical composition is very wide. Nearly all the varieties of these rocks appear in these islands, and consequently a description of the Ulfö-occurrences may also serve for the large areas occupied by these rocks, not only within the limits of this district, but probably in many other regions of Norrland.

The mineralogical composition is: *plagioclase, orthoclase, quartz, pyroxene, olivine, titaniferous magnetite, biotite, apatite*. The most common varieties are without orthoclase and quartz. Other varieties consist, for the most part, of titaniferous magnetite, which forms the titaniferous iron-ores of Ulfö. There are rocks consisting principally of olivine, and others of plagioclase. In these islands I have not observed pyroxenites, but such rocks occur on Ellön. They are not pyroxenites in the proper sense, but are very rich in pyroxene.

Besides this, there occur monzonitic rocks, which may be considered as belonging to the same group as the above-named. These are rocks in which the feldspars are the most important constituents, and the proportions of lime-bearing feldspars are about the same as the proportions of orthoclase.

Moreover, there occur dike-rocks of interesting constitution, as well as mixed rocks — results of the melting of granitic fragments by the diabase magma.

Consequently, we have in the Post-Jotnian rocks examples of very wide differentiation. It may be said that there occur rocks principally consisting of each of the minerals which compose the general type. They are, consequently, very extreme products of differentiation. Besides this, there are evident instances of the genesis of igneous rocks by solution of older rocks, which process is also accompanied by differentiation.

[1] Om Rödöområdets rapakivi och gångbergarter, p. 15. Sveriges Geol. Undersökning. Ser. C. N:o 181. — 1899.

The Diabase.

The rock from the quarry west of Hamnberget (N. Ulfön) is a fresh, grey-coloured variety. In weathered surfaces darker colours appear.

The most important constituents are discernible by the unaided eye. One can see that the dark and the light constituents are present in about equal quantities. The mineral that appears in greatest amount is plagioclase, then come olivine and augite.

The rock is phanerocrystalline and millimeter-grained. Although the crystals in this rock are of varying sizes, one can say that they belong to the same order of magnitude.

The fabric is equigranular. The crystals are not equant. Generally the feldspars are nearly tabular. The olivines are irregular, but in most cases show rounded forms. The pyroxene presents very irregular forms, as do the biotite and titaniferous magnetite. Consequently, as regards the shape of the crystals, the rock is multiform.

The mineralogical composition[1] is: *feldspars, olivine, augite, titaniferous magnetite, biotite, apatite, pyrite,* and some decomposition-products.

Feldspars. The plagioclases are white and little altered. They are always twinned and show a very marked zonal structure. The most common is the albite twin, which is found alone as well as in combination with pericline and Carlsbad twinning.

They are tabular, flattened according to (010). The largest observed dimensions are: 6 mm. in the direction of the a-axis, 3 to 4 mm. in the direction of the c-axis, and 1 to 2 mm. in the direction of the b-axis. Generally they are smaller — about 3 or 4 mm. in length, and of nearly the above-mentioned proportions.

The shapes of the plagioclase crystals are nearly anhedral, sometimes subhedral. This is not the case with all varieties of this rock. As we shall see later, the crystallisation-relation between the different minerals depends upon the greater or less quantity of the mineral in question present in the rock. I mean that, in varieties rich in plagioclase and poor in femic constituents, the feldspars have a tendency to become well-faced. In varieties rich in augite, the augite has the same tendency. This rule is applicable in the case of olivine, too, under analogous circumstances.

The innermost feldspar is the most calcic, usually an acid bytownite, and that from the peripheric zone is an oligoclase; sometimes it is observed that the outer zone is oligoclase-albite and even albite.

Section at right angles to (010) and (001)	010 cleavage	Ext'n	Ext'n angle		
The most calcic zone	58,0	97,2	+ 39,2	Ab_{19}	An_{81}
» » sodic »	58,0	50,0	— 8,0	Ab_{88}	An_{12}

The greater part of this crystal has a labradoritic composition. It is always found that the most calcic, and especially the most sodic zones

[1] A. E. Törnebohm, Om Sveriges vigtigare Diabas och Gabbro arter; Kongl. Svenska Vetenskaps-Akademiens Handlingar, 1877 Vol. 14, N:o 13.

are very thin. As a consequence of this, we find that the bulk of the crystals are labradoritic.

The contact between the oligoclase and the andesine zones is charply defined, and similarly that between the andesine and the labradoritic zones.

Section parallel to (010)	(001) cleavage	Ext'n	Ext'n angle		
»	40°,0	10,0	— 30,0	Ab_{23}	An_{77}
»	40°,0	28,0	— 12,0	Ab_{55}	An_{45}
»	40°,0	46,0	+ 6,0	Ab_{77}	An_{23}

There are small labradoritic and bytownitic crystals, about 1 mm. in length, as inclusions in the bigger plagioclases.

They are not to be regarded as a separate, younger generation, but are probably contemporaneous with, or a little older than, the kernel of the bigger, zonal-structured plagioclases.

The contacts between the zonal feldspars are very irregular. They tooth with each other, and sometimes there is an implication, limited to the peripheries, in such a manner that small pieces of one of them are inclosed in the other.

Augite. — The augite has a reddish-brown colour with occasional violet tints. The pleochroism is hardly noticeable in slices of the thickness of about 0,02 mm., but it is more perceptible in directions oblique to the axes.

Z = yellowish- to reddish-brown; Y = reddish-brown; X = yellowish- to reddish-brown and reddish-violet.

Dispersion distinct, $\rho > \nu$. The dispersion is greater for the axis A than for A'.

All the other minerals are present as inclusions in the augite. There are rows of very small microlites; they are probably magnetite microlites.

The augite shows only very few traces of decomposition: in some places there is a change of the reddish-brown colour to pale green, and that is all.

This mineral is only of secondary importance in comparison with the feldspars and olivine.

Sometimes it is observed that several crystals in a limited region of the slice have the same orientation, as if they were parts of a single crystal separated by olivine and plagioclases. As a consequence of its small quantity, the augite crystals are quite anhedral.

Olivine has a whitish-yellow colour with a greenish tint. It occurs as rounded crystals, about 2 mm. in diameter, and follows the feldspars in importance. It is the mineral which began to crystallize next after the apatite. The olivine is only very slightly decomposed, but not so fresh as the augite. The observed alteration-product is a green mineral, with low refraction and double refraction; is is probably serpentine. Sometimes a

faint pleochroism is to be noticed. The alteration takes place in the usual way, along the cleavage and fracture lines, and from the outer part of the crystals; sometimes the alteration is accompanied by the separation of magnetite. Inclusions of apatite and magnetite, in the form of rods, are numerous, and there are other inclusions of a mineral which may be spinel- in lines which run through the crystals in all directions. It appears that this olivine is a variety rich in iron.

Titaniferous magnetite. — The titaniferous magnetite commenced its crystallisation immediately after the olivine, and is nearly always surrounded by biotite. It seldom occurs in well-faced crystals.

Biotite. The absorption formula is Z = Y = dark brownish-red, X = light yellow.

The angle of the optic axes is extremely small. Twinning has been observed, on the mica law, but it is not common. The crystals are always anhedral. The mineral generally occurs enveloping the titaniferous magnetite. It may happen that independent crystals are observed, but that is only apparent, and will depend upon how the section is cut through the crystal; a peripheric section shows only mica, but a section through the centre of the crystal may show titaniferous magnetite inclosed by biotite.

The limits of the biotite against the other minerals are very irregular. Sometimes it is observed that the biotite shows a kind of interpenetration, especially with the plagioclases. Both minerals penetrate the one into the other, forming a kind of implication. The biotite, when surrounding the titaniferous magnetite, generally occurs in a cluster of crystals, and some of them are composed of fan-like, radiating aggregations.

The biotite is not very decomposed; here and there it changes in colour, from brownish to green. This is the first step in the change to chlorite.

Apatite is the oldest mineral in the rock, and generally occurs in subhedral crystals of about 1 mm. in length, and of prismoid form. Irregular, rounded crystals are not unfrequent.

Pyrite occurs in small quantites in this rock, as irregular, sometimes rounded, small crystals.

Analysis shows that the rock of the quarry west of Hamnberget is a rock of the so-called calc-alcali series. The proportion of Na_2O is slight, but nearly double that of K_2O, and, as is well-known, a low proportion of alkalies is typical of the most basic rocks of the above-named series. The proportions of MgO and CaO are not very high, but they are those commonly found in diabases, dolerites and basalts. The proportions of iron oxides is perhaps extraordinarily high. The SiO_2, Al_2O_3 and other constituents do not show anything specially noteworthy, as has been stated above. The quantitative mineralogical composition is very variable, and consequently the chemical constitution varies likewise. For that reason it should be remembered that the analysis is not necessarily

TABLE II.

Auvergnose[1] (olivine-diabase). From the quarry west of Hamnberget, N. Ulfön. (Analyst, N. Sahlbom.)

	Per cent	Mol.	Mol. per cent
H_2O	0,14	—	—
H_2O	0,58	—	—
SiO_2	45,64	0,7607	49,55
TiO_2	1,84	0,0230	1,50
Al_2O_3	15,61	0,1530	9,96
Fe_2O_3	2,17	0,0136	—
FeO	14,97	0,2079	15,31
MnO	0,28	0,0039	0,25
CaO	7,04	0,1257	8,19
BaO	0,02	0,0001	0,01
MgO	7,60	0,1900	12,37
K_2O	1,29	0,0137	0,89
Na_2O	1,68	0,0271	1,77
P_2O_5	0,42	0,0030	0,20
S	0,19	0,0059	—
Cl	0,06	0,0017	—
Fl	0,19	0,0100	—
	99,72		100,00
O for Fl_2	0,08		
	99,64		

Quantitative Classification.

Formula	Mol.	Wt.		Norm.				
$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	137	× 556	= Orthoclase	= 7,617	F	53,009	Sal	53,009
$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$	271	× 524	= Albite	= 14,200				
$CaO \cdot Al_2O_3 \cdot 2SiO_2$	1122	× 278	= Anorthite	= 31,192				
$MgO \cdot SiO_2$	1153	× 100	= Hypersthene	= 25,377	P + O	37,532	Fem	46,094
$(Fe,Mn)O \cdot SiO_2$	1049	× 132						
$2MgO \cdot SiO_2$	747	× 70	= Olivine	= 12,155				
$2FeO \cdot SiO_2$	679	× 102						
$FeO \cdot Fe_2O_3$	136	× 232	= Magnetite	= 3,155	M	6,651		
$FeO \cdot TiO_2$	230	× 152	= Ilmenite	= 3,496				
$3CaO \cdot P_2O_5$	30	× 310	= Apatite	= 0,930	A	1,911		
FeS_2	59	× 120	= Pyrite	= 0,708				
CaF_2	35	× 78	= Fluorite	= 0,273				

Class III **Order 5** **Rang 4** **Subrang 4**

$$\frac{Sal}{Fem} = \frac{53,01}{46,09} = < \frac{5}{3} > \frac{3}{5}; \quad \frac{Q}{F} = \frac{0}{53,01} < \frac{1}{7}; \quad \frac{K_2O + Na_2O}{CaO} = \frac{408}{1257} < \frac{3}{5} > \frac{1}{7}; \quad \frac{K_2O}{Na_2O} = \frac{137}{271} < \frac{3}{5}$$

Salfemane **Gallare** **Auvergnase** **Auvergnose**

Osann's Classification.

s = 51,25 n = 6,65
A = 2,66 a = 1,37 k = 0,86.
C = 7,30 c = 3,76
F = 28,83 f = 14,87

[1] The sample has been dried at 105°. $H_2O = 0,14$. SrO, CrO_3, NiO, CoO, CuO, ZrO_2, SnO_2 are not present.

accurate for every occurrence of the rock. Examples of the great diversity in the chemical composition of this rock are found everywhere. It is not only that one notices slight changes, which take place progressively in the rock-mass, but there occur streaks, showing abrupt changes in composition.

This rock sometimes appears banded[1] in a very regular manner, very similarly to the gabbros of Skye.[2] See Plate V, Fig. 1. The difference in composition between two consecutive bands is not great. What the banding is due to is the varying proportions of the ferro-magnesian minerals, and it was produced by the flow of the heterogenous magma. In these islands it is observed that the planes of contact between the bands do not lie far out of the horizontal plane. In the following pages will be described other examples which testify to the great heterogeneity of the diabase magma.

It has been said that this rock has a typical ophitic fabric. The ophitic fabric, as IDDINGS has pointed out, is a variety of the poikilitic fabric. In the ophitic fabric we find that the lime-soda-feldspars are tabular and somewhat uniformly scattered, in relatively large crystals throughout a bigger crystal, which serves as matrix. The plagioclases must, consequently, be older than the matrix mineral. In our case we certainly get the lime-soda-feldspars tabular, but they are not older than the other minerals; moreover, the augite, which is the only mineral that could serve as matrix, is found in very limited quantities. The first crystallised mineral is the apatite; then begins the olivine; immediately after begins the crystallisation of the magnetite and biotite, and, before the crystallisation of the olivine and magnetite is complete, that of the plagioclase commences; and finally the augite commences its crystallisation, before that of the plagioclase is ended. See Plate VII. Thus there would have been possibilities of ophitic fabric in the event of the augites having been represented in greater quantities of course-within certain limits. More graphically expressed, we have the following sequence in the crystallisation:

Apatite.
Olivine.
Magnetite-biotite.
Plagioclases.
Augite.

ROSENBUSH, when speaking of olivine-diabases, says[3] that «Mit zunehmenden feldspatgehalt wird die Struktur bei wachsender Korngrösse vollkommen gabbroide (Åsby-diabas); . . .»

[1] HÖGBOM, The igneous rocks of Ragunda, Alnö, Rödö and Nordingrå. — GEIKIE, «Sur la structure rubannée der plus anciens Gneiss et des Gabbros Tertiaires», Compt. rend. Cong. Géol. Internat. 1894, p. 139. »Ancient Volcanoes of Great Britain», Vol. II. 1897.

[2] GEIKIE and TEALL, Quar. Journ. Geol. Soc. London. Vol. 50, p. 645. — HARKER, Memoirs Geol. Survey. United Kingdom. Glasgow 1904.

[3] Elemente der Gesteinslehre p. 418.

The same author expresses the following opinion with respect to some diabase-dikes that HOVEY studied in the neighbourhood of Rio de Janeiro:[1] «Bei mächtigen Gängen zeigte sich die Struktur holokristallin und zwar gabbroide bei hohem Feldspat, ophitisch bei hohem Augitgehalt.»

I have come to a different conclusion after my studies on the Ulfö-diabase (Åsby-type) region.

I have observed in the Ulfö-diabase that, when a mineral increases in quantity, it becomes more and more euhedral; but when its quantity decreases it becomes more and more anhedral.

I shall discuss that question more fully when I describe the other rocks which support this assertion; here I will only add that there is a variety of the Ulfö-diabase which is very near an anorthosite; it is composed of plagioclase with a small quantity of augite; and, consequently, according to ROSENBUSCH, the conditions are propitious for a gabbroid fabric. But we find, instead, a tendency to the ophitic fabric, just as a consequence of the great proportion of plagioclase, which assumes subhedral forms, and the limited quantity of augite, the paucity of which causes this mineral to solidify in anhedral crystals.

Although I am conscious of its inapplicability, I use the term diabase (Ulfö-diabase), because its use is inveterate in Swedish petrographical literature. TÖRNEBOHM also had scruples about using that term in his work on the Swedish diabases.

The Titaniferous Iron-Ore.

In several localities of the diabase-regions occurs titaniferous iron-ore as a product of the differentiation of the magma of which the diabase itself is a differentiation-product.[2]

LUNDBOHM describes these occurrences as follows: «Two of the mines on S. Ulfön occur in the neighbourhood of the fishing-village of Marviksgrundet, and in one of these, the southern Grundet mine, occurs a band of 1,8 to 3,0 m. in thickness, rich in iron, the dip of which is some degrees to the SSE. The mine has been worked in two galleries, one of which lies so low that, during bad weather, the sea-water comes in. The other has been worked in several small tunnellings. The other mines are of less importance, and the ore produced is less in quantity.

On N. Ulfön have been worked «Jakobs norra skärpning» (the north

[1] Mikroskopische Physiographie der Mineralien und Gesteine. Band II; Zweite Hälfte. Ergussgesteine. Stuttgart 1908, p. 1209.

[2] ERDMANN, «Om den titanhaltiga jernmalmen från Ulföarne.» Öfversigt af Vet. Akad. Förh. 1848, p. 11. — LUNDBOHM, Berggrunden inom Vesternorrlands län, p. 45. — HÖGBOM, The igneous rocks of Ragunda, Alnö, Rödö and Nordingrå. 1910, p. 27.

Jacob mine) and «Jakobs södra skärpning» (the south Jacob mine), which lie to the east of Norrbyn, not far distant from the eastern coast of the island, and Oxmyrgrufvan to the ESE of Sörbyn. The first-named is established over a rather extensive bank 0,30 to 0,45 m. in thickness, which is rather rich in iron, and which dips some degrees to the west. Above and below this bank there appear several narrower belts of iron-ore, which occur with such regularity that the rock looks as though it were stratified. The undermost bank, which is the thickest, was exposed over a rather large area, and for this reason it has been easily worked. After this supply was finished the bank was followed, a large gallery being run in under a high hill, and from this gallery were opened out several side-shafts, which were connected, columns being left as supports. The same bank has been worked in «Jakobs södra skärpning», but in this place it is exposed only at the foot of the steep hill. In Oxmyrgrufvan, where the bank is about 0,30 m. in thickness, it has been worked only to a limited extent.»

LUNDBOHM, moreover, communicates some historical data of interest, taken from the reports of the mine-surveyors. In 1797 a company was formed for working the mines of Ulfö. The amount of iron in the ores of N. Ulfön, which was named «Jern-Ulfön» (Iron-Ulfön) was reckoned at 29 %, and the thickness of the iron-ore banks was set down at 2,4—5 «kvarters» (1 kvarter = 6 inches). The occurrences in the region of the fishing-village of Marviken in S. Ulfön were set down at between 6 and 7 kvarters in thickness. Besides this, the fact is mentioned that the mines were worked about the years 1760—70, but were soon abandoned.

We learn that, when trial blowings were made at Bollsta in 1802, the yield was poor and consisted of red-short iron — a statement that is at variance with other reports.

Under 1826 appears the entry that the proportion of iron varied between 18 % and 42 %; under 1828 we read that, at the trial blowings made at Lögdö, the ore appeared to be difficult to fuse, but that, if mixed with another ore, which yields only red-short iron, it removes this defect from the latter.

In 1829 a company was formed by the owners of the ironworks of Bollsta, Lögdö, Sörfors and Långvind, and during the years 1830—1846 8,829 tons were worked in N. Ulfön; and in 1835 and 1837 232 tons were worked in Trysundaön. During the years 1871—1876 the production was 4,791 tons.

During recent years many other occurrences of titaniferous iron-ore have been found in Ulföarna by Mr. J. W. NORDVALL, of Vattjom. The deposits occur in several localities extending from Grunna, in the south, to Fäbodviken, in Ulfö sound, and continue along the northern shore of the southern island as far as about 500 m. to the NE of Fäbodviken.

In the neighbourhood of Grunna the iron-ore appears in banks at three different levels. The highest bank, at about 10 or 12 m. above the sea (in

the steep escarpement to the south of the fishermen's huts) has a maximum thickness of 1,80 m. This bank rises to the northward, and it appears that the bank of poor ore which occurs at about 250 m. to the NE of the huts is the continuation of it. In this locality it has a thickness of about 0,30 m. and is about 20 m. above the sea.

The second bank, which appears south of the huts at 7 m. above the sea and has a maximum thickness of 3,00 m., seems not to be so long as the highest bank. The third is less important, being only 0,45 m. in thickness. It occurs at 5 m. above the sea at a place east of the huts.

These exposures appear in steep escarpments of the diabase, which face west and extend for a distance of about 2 km. from the hill SSE of Grunna in a NNE direction. The ores seem to occur in very flattened lenses and bands, which are of the same kind as those of the common diabase described above.

The titaniferous iron-ore occurs also in the form of irregular accumulations and streaks. Such irregular occurrences are described by LUNDBOHM from the eastern region of Björnviken, in Trysundaön. I have observed analogous accumulations in the neighbourhood of the fishing-village of Grisslan.

The diabase of the small islets Värsingsklubbarna is very rich in titaniferous magnetite, and at the same time presents a beautiful texture, in which the crystals are parallel to a nearly horizontal plane. IDDINGS states[1] that rocks which are homogeneous in composition and texture may be characterised by parallel or sub-parallel, tabular or prismatic crystals of mica, feldspar or hornblende, which produce a laminated texture; and he adds that this is the texture of some gneissic rocks, which may, in certain cases, be unaltered igneous rocks, in which some of the crystals are arranged in nearly parallel positions by the movement or flow of the magma during crystallisation. On p. 222, when writing on the subject of the arrangement of tabular crystals in equigranular rocks, he characterises the parallel arrangement as that in which almost all the crystals are parallel to one another, or very nearly so; in which latter case they are said to be subparallel. In the case of the Post-Jotnian rocks it sometimes happens that the crystals are parallel, not with each other, but only with a certain plane, and they may even occur in whirls. For that reason I use the old term »flow-texture». This texture is very common in all the varieties of the Post-Jotnian diabases and monzonites that are rich in plagioclase, or in feldspars and pyroxene. In those varieties showing flow-texture the plagioclases generally appear lying over on their (010) faces, so that, in a slice cut parallel to the plane of flow, one nearly always gets sections according to (010).

The titaniferous iron-ore of Grunna (S. Ulfön) consists of: *titaniferous*

[1] Igneous rocks p. 243.

TABLE III.

Titaniferous iron-ore. Grunna, S. Ulfön.
(Analyst, N. Sahlbom.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°)	0,15	—	—
H_2O (above 105°)	0,66	—	—
SiO_2	23,16	0,3860	26,13
TiO_2	6,61	0,0826	5,59
ZrO_2	0,02	0,0002	0,01
Al_2O_3	5,64	0,0553	3,75
Fe_2O_3	17,64	0,1102	—
Cr_2O_3	0,80	0,0052	—
FeO	32,78	0,4553	46,46
MnO	0,78	0,0110	0,74
NiO	0,20	0,0027	0,18
CoO	traces	—	—
CuO	traces	—	—
SnO_2	0,00	0,0000	—
CaO	2,31	0,0412	2,79
BaO	0,01	0,0001	0,01
MgO	7,73	0,1932	13,08
K_2O	0,26	0,0028	0,19
Na_2O	0,96	0,0155	1,05
P_2O_5	0,04	0,0003	0,02
Vd_2O_5	0,08	0,0004	—
S	0,16	0,0050	—
Cl	0,04	0,0011	—
Fl	0,02	0,0011	—
C	0,00	0,0000	—
	100,05		
O for Fl_2, Cl_2 and S	0,09		
	99,96		

Quantitative Classification.

Formula	Mol.	WT		Norm				
$K_2O . Al_2O_3 . 6 SiO_2$	28	× 556	= Orthoclase	= 1,557	F	19,965	Sal	19,965
$Na_2O . Al_2O_3 . 6 SiO_2$	155	× 524	= Albite	= 8,122				
$CaO . Al_2O_3 . 2 SiO_2$	370	× 278	= Anorthite	= 10,286				
$CaO . SiO_2$	43	× 116						
$MgO . SiO_2$	20	× 100	= Diopside	= 1,003				
$FeO . SiO_2$	23	× 132			P + O	35,292	Fem	79,317
$2 MgO . SiO_2$	1614	× 70	= Olivine	= 34,289				
$2 FeO . SiO_2$	2254	× 102						
(Mg, Fe)O	295	× 40	= (Mg, Fe) O	= 4,139				
	411	× 72						
$FeO . Fe_2O_3$	1102	× 232	= Magnetite	= 25,566	M	43,425		
$FeO . Cr_2O_3$	52	× 224	= Chromite	= 1,165				
$FeO . TiO_2$	826	× 152	= Ilmenite	= 12,555				
FeS_2	50	× 120	= Pyrite	= 0,600	A	0,600		

Class IV	Subclass 1	Order 3	Section 5
$\frac{Sal}{Fem} = \frac{19,97}{79,32} < \frac{3}{5} > \frac{1}{7}$;	$\frac{POM}{A} > \frac{7}{1}$;	$\frac{P+O}{M} = \frac{35,29}{43,43} < \frac{5}{3} > \frac{3}{5}$;	$\frac{P}{O} = \frac{1,00}{34,29} < \frac{1}{7}$
Dofemane	Dofemone	Sverigare	Sverigiare

Rang 1	Section 1	Subrang 4
$\frac{(Mg, Fe) O + CaO}{K_2O + Na_2O} = \frac{7034}{183} > \frac{7}{1}$;	$\frac{(Mg, Fe) O}{CaO} = \frac{6622}{412} > \frac{7}{1}$;	$\frac{MgO}{FeO} = \frac{1932}{4690} < \frac{3}{5} > \frac{1}{7}$
Tabergase	Tabergiase	

Osann's classification.

s = 31,75 n = 9,81
A = 1,07 a = 0,33 k = 0,44
C = 2,68 c = 0,83
F = 60,58 f = 18,84

magnetite, olivine, plagioclase and *augite,* as essential minerals, and *biotite* as accessory constituent. *Apatite* is very rare.

The minerals appear to be the same as in the diabase from the quarry west of Hamnberget. The order of crystallisation has been:

Magnetite,
Olivine,
Plagioclase,
Augite,

which is in conformity with the proportions of the minerals in the rock. Magnetite occurs in greatest amount and crystallises first; then comes olivine, which is the mineral second in quantity and in order of separation as well, and so on with the other minerals. See Plate VIII.

It may be stated that in some varieties — as in the sample analysed — I have not observed overlapping in the crystallisation of magnetite and olivine, and there are also varieties showing no overlapping between olivine and plagioclase. This is the case when the plagioclase occurs in very small amounts. A noteworthy fact is that apatite is almost absent from the varieties comparatively rich in magnetite and olivine. The biotite crystallises surrounding the iron mineral, in spite of its limited quantity. The quantities of biotite in the sample analysed are so limited that that mineral may be considered as accessory.

The crystals of titaniferous magnetite are generally small, in most cases showing sections less than 0,10 mm.^{2} in area. They are generally subhedral and anhedral. When anhedral their sections are generally rounded.

The *olivine* occurs in subhedral and anhedral crystals of sections somewhat below 1 mm.^{2} in area.

The *plagioclase* crystals are always anhedral. The sections in some cases attain dimensions of between 1 and 2 mm.^{2}

The *augite* occurs in irregularly shaped crystals of about the same dimensions as those of the plagioclases.

Chemically this rock is very analogous to that of Taberg,[1] a hill of about 150 m. in altitude, which lies about 15 km. to the south of the town of Jönköping, in Småland. The amounts of SiO_2, TiO_2, Al_2O_3, Mn and iron are nearly the same; the amount of Vd_2O_5 is also about the same. The greatest difference lies in the amounts of MgO. But the analyses for the Taberg rock appears to lack exactness, so that a close comparison may

[1] A. Sjögren. Om förekomsten af Tabergs jernmalmfyndighet i Småland. Geol. För. Förh. 1876—77. — A. E. Törnebohm. Om Taberg i Småland och ett par därmed analoga järnmalmförekomster. Geol. För. Förh. 1881. — J. H. L. Vogt. Om dannelsen af de vigtigste i Norge og Sverige representerede grupper af jernmalmsförekomster. Geol. För. Förh. 1891. — Über die Bildung von Erzlagerstatten durch magmatische Differentiation. Fortschritte der Mineralogie, Kristallographie und Petrographie, p. 24. Herausgegeben im Auftrag der Deutschen Mineralogischen Gesellschaft von G. Linck. Zweiter Band. 1912. — Excursions in the Archæan of Southern Sweden by H. G. Högbom, A. Gavelin and H. Hedström. Congrès Geol. Int. 1910, p. 57.

be misleading. Besides the presence of Vd_2O_5, the quantities of Cr_2O_3 and NiO in this rock are remarkable. The genesis of both occurrences appears to be analogous. The iron-ore of Taberg is enclosed by a hyperite, and it is considered that these rocks are differentiation-products of the same magma.

There are transition-forms between this rock, the common diabase, the peridotites, the monzonites and the pyroxenitic rocks.

All the varieties of titaniferous iron-ore are very rich in olivine.

The peridotites.

I have observed these rocks only in the form of streaks. They occur in the common diabase in company with streaks of anorthositic composition. Sometimes both rocks appear in sharp contact with each other. These rocks sometimes occur in the form of fragmentary inclusions, but this phenomenon is perhaps only apparent, depending upon the direction of the section that cuts the streak. It is an unaltered, dark greenish rock, which, macroscopically, appears with an even texture.

It consists principally of *olivine* and *pyroxene*, the proportion of olivine being much greater than that of pyroxene. Besides these minerals occurs *plagioclase*, but the proportion is only about half that of pyroxene. *Titaniferous magnetite* appears in such quantities as to lead us to class this constituent among the accessory minerals: it is almost always surrounded by *biotite*. The other accessory constituents observed are *apatite*, in very small amounts, and *pyrrhotite*. According to the analysis there is some *zircon*, but I did not observe it.

The *olivine* is a variety rich in iron, and it appears to be identical with that occurring in the common diabases and iron-ores. The axial angle is large and the sign is negative. The dispersion is $\rho > \upsilon$. The olivine crystals are anhedral and sometimes subhedral. The mean area of their sections is about 1 mm.^{2} With the exception of apatite, olivine is the first mineral to crystallise. The olivine is sometimes altered to serpentine and magnetite.

The *pyroxene* is of the same variety as that occurring in the diabase. It appears in very irregular shapes; sometimes in relatively large crystals, whose sections attain 8 to 10 mm.^{2} Sometimes those large augite crystals include many olivine crystals of different orientation, and when these are relatively small we have a poikilitic fabric.

The *plagioclase* occurs in very irregular crystals. Whether the plagioclase crystallised before the augite, or not, I could not decide. Their contacts throw no light on that question, and I have seen neither inclusions of plagioclase in augite, nor of augite in plagioclase. In a variety richer in plagioclase I have observed a very small grain of this mineral included in olivine, and that grain contained two small magnetite inclusions, one of them surrounded by biotite. These inclusions occur, perhaps, in the

TABLE IV.

Custerose (Peridotite). Västra Värnsingen. (An islet 1 km. to the NE of N. Ulfön.) (Analyst, M. WUNDER.)

	Per cent	Mol.	Mol. per cent
H_2O (below 110°)	0,08	—	—
H_2O (above 110°)	1,42	—	—
SiO_2	39,43	0,6572	38,15
TiO_2	1,22	0,0152	0,88
ZrO_2	0,10	0,0008	0,05
Al_2O_3	4,47	0,0438	2,54
Fe_2O_3	2,70	0,0169	—
Cr_2O_3	0,00	0,0000	—
FeO	23,38	0,3247	20,83
MnO	0,52	0,0073	0,42
NiO	0,22	0,0029	0,17
CoO	0,07	0,0009	0,05
CaO	3,52	0,0629	3,65
BaO	0,19	0,0013	0,07
MgO	22,46	0,5615	32,59
K_2O	0,30	0,0032	0,18
Na_2O	0,36	0,0058	0,34
P_2O_5	0,20	0,0014	0,08
S	0,15	0,0046	—
	100,79		

Quantitative Classification.

Formula	Mol.	Wt.		Norm				
$ZrO_2 . SiO_2$	8	× 183	= Zircon	= 0,146	Z	0,15	Sal	14,64
$K_2O . Al_2O_3 . 6\,SiO_2$	32	× 556	= Orthoclase	= 1,779				
$Na_2O . Al_2O_3 . 6\,SiO_2$	58	× 524	= Albite	= 3,039	F	14,49		
$CaO . Al_2O_3 . 2\,SiO_2$	348	× 278	= Anorthite	= 9,674				
$CaO . SiO_2$	247	× 116						
$MgO . SiO_2$	160	× 100	= Diopside	= 5,515				
$FeO . SiO_2$	87	× 132						
$MgO . SiO_2$	927	× 100			P	19,52		
$FeO . SiO_2$	359	× 132	= Hypersthene	= 14,009				
$2\,MgO . SiO_2$	4528	× 70						
$2\,FeO . SiO_2$	2568	× 102	= Olivine	= 57,890	O	57,89	Fem	84,63
$FeO . Fe_2O_3$	169	× 232	= Magnetite	= 3,921				
$FeO . TiO_2$	152	× 152	= Ilmenite	= 2,310	M	6,23		
$3\,CaO . P_2O_5$	14	× 310	= Apatite	= 0,434				
FeS_2	46	× 120	= Pyrite	= 0,552	A	0,99		

Class IV — Subclass 1 — Order 1 — Section 4

$$\frac{\text{Sal}}{\text{Fem}} = \frac{14,64}{84,63} < \frac{3}{5} > \frac{1}{7}; \quad \frac{\text{POM}}{\text{A}} > \frac{7}{1}; \quad \frac{\text{P} + \text{O}}{\text{M}} > \frac{7}{1}; \quad \frac{\text{P}}{\text{O}} = \frac{19,52}{57,89} < \frac{3}{5} > \frac{1}{7}$$

Dofemane — Dofemone — Hungarare

Rang 1 — Section 1. — Subrang 2

$$\frac{(Mg, Fe)\,O + CaO}{K_2O + Na_2O} = \frac{0,9615}{0,0090} > \frac{7}{1}; \quad \frac{(Mg, Fe)\,O}{CaO} = \frac{0,8973}{0,0642} > \frac{7}{1}; \quad \frac{MgO}{FeO} = \frac{0,5615}{0,3358} < \frac{7}{1} > \frac{5}{3}$$

Cortlandtase — Cortlandtiase — Custerose

Osann's Classification.

s = 39,16 n = 6,54
A = 0,52 a = 0,18 k = 0,62
C = 2,02 c = 0,69
F = 55,76 f = 19,13

peripherical regions of the olivine crystal. The sections of plagioclase vary in area. They have, perhaps, an average area of about 1 mm.^{2}

The *titaniferous magnetite* occurs surrounded by biotite, and it has crystallised before the plagioclase and augite, but after the olivine. The sections of the magnetite are always less than 1 mm.^{2} in area. The order of crystallisation in this rock is:

Apatite,
Olivine,
Magnetite and biotite,
Augite and plagioclase,
Orthoclase.

The order of crystallisation is illustrated in Plate VI, Fig. 1.

This rock is millimeter grained, and the fabric may be classed as equigranular, the olivine crystals being those which determine the pattern.

Chemically this rock is characterised, as most peridotites are, by the small amounts of SiO_2, Al_2O_3, CaO and alkalies, and the great quantities of MgO and iron. This is because the olivine is a variety rich in iron. Besides this, the analyses show small amounts of NiO and CoO; but Cr_2O_3 does not occur. It may be remembered that there was a not insignificant quantitity of Cr_2O_3 in the titaniferous iron-ore. This rock is somewhat like the wehrlites.

The anorthosites.

These rocks occur as streaks in the ordinary diabase, sometimes together with, and in sharp contact with the peridotites; sometimes they appear in company with the iron-ores too. Besides this, I have observed them as short, narrow dikes, sharply separated from the country-rock. They never occur in large masses.

The mineralogical composition is qualitatively the same as in the diabase and the related rocks described above, excepting that, in this rock, orthoclase has been detected.

The *plagioclases* are zonally built, and occur as the most important constituents of the rock. They appear in tabular crystals, flattened according to (010). There occur crystals which, in the direction of the c-axis, attain more than 5 mm. in length. On (010) they show a sectional area of about 4 mm.^{2} In the kernels of the crystals, in sections cut parallel to (010), I found an extinction angle of -31° and of 0° in the peripherical parts of the crystals. Consequently, their composition ranges from a bytownite, $Ab_{20}An_{80}$, in the kernel, to an oligoclase-andesine, $Ab_{69}An_{31}$, in the periphery. The crystals are subhedral and anhedral. They are generally toothed with each other at the contacts. Augite is the most common mineral after the plagioclases

and always occurs in anhedral crystals. Sometimes, when the augite occurs in large crystals, ophitic fabric is produced. This is shown in Plate IX, Fig. 1. Some of these large crystals attain sections of over 50 mm.^{2}

Magnetite generally occurs surrounded by biotite. The crystals are always anhedral and seem sometimes to be relatively large, occurring with sections of about 20 mm.^{2}

Olivine sometimes appears in small amounts. In slices from the rock analysed I have not found olivine, but in analogous rocks from other regions, for instance in that from the streaks in the northern region of Norrsand, occurs olivine. The olivine grains are anhedral and elongated, and present somewhat rounded contours. Their forms generally depend upon those of the plagioclases. The average sections are about 0,30 mm.^{2} in area. The grains are surrounded by a greenish, and even by brown mica, and by some white amphibole. The latter appears between the mica and the olivine, and occurs in very small grains. The olivine appears to be a variety very rich in iron, and it is very fresh.

In the analysed rock occur very small amounts of *apatite,* though in large crystals. There are crystals which, in the direction of the c-axis, have a length of 5 mm., and, in a direction perpendicular to it, about 0,30 mm. (in the middle of the crystal). In other varieties of this rock the apatite crystals are of less magnitude, but more numerous.

Orthoclase has been observed in small amount, but its sections may sometimes attain 2 mm.^{2}

This rock may be considered as equigranular, or nearly so, because the mineral on which the pattern depends is plagioclase, the plagioclase crystals being of the same order of magnitude. The rock is, moreover, millimeter-grained. It may be added that poikilitic fabric is locally developed.

Flow-texture is very common in these rocks, the plagioclase crystals taking a sub-parallel position.

The order of crystallisation in the analysed rock is:

Apatite,
Plagioclase,
Magnetite
and
Biotite,
Augite,
Orthoclase.

See Plate IX.

When olivine occurs it appears that its crystallisation has taken place after the separation of the magnetite and biotite. In the last case the rock approaches the troctolites, but only those which contain olivine rich in iron.

Chemically, as is seen from Table V, the rock shows the common characteristics of analogous varieties occurring in other districts.

TABLE V.

Hessose (Anorthosite). Västra Värnsingen. (Analyst, M. WUNDER.)

	Per cent	Mol.	Mol. per cent
H_2O (below 110°) . .	0,15	—	—
H_2O (above 110°) . .	1,25	—	—
SiO_2	48,80	0,8133	55,739
TiO_2	2,40	0,0300	2,056
ZrO_2	0,15	0,0012	0,082
Al_2O_3	22,08	0,2165	14,838
Fe_2O_3	3,20	0,0200	—
FeO	5,28	0,0733	7,765
MnO	0,14	0,0020	0,137
CaO	10,73	0,1916	13,132
MgO	1,65	0,0412	2,824
K_2O	1,04	0,0111	0,761
Na_2O	2,11	0,0340	2,330
P_2O_5	0,70	0,0049	0,336
S	0,17	0,0053	—
	99,85		

Quantitative Classification.

Formula	Mol.	Wt.		Norm				
SiO_2	1309	× 60	= Quartz	= 7,854	Q	7,854	Sal	79,709
$ZrO_2 . SiO_2$	12	× 183	= Zircon	= 0,220	Z	0,220		
$K_2O . Al_2O_3 . 6 SiO_2$	111	× 556	= Orthoclase	= 6,172	F	71,635		
$Na_2O . Al_2O_3 . 6 SiO_2$	340	× 524	= Albite	= 17,816				
$CaO . Al_2O_3 . 2 SiO_2$	1714	× 278	= Anorthite	= 47,647				
$CaO . SiO_2$	39	× 116						
$MgO . SiO_2$	25	× 100	= Diopside	= 0,887	P	7,568	Fem	18,923
$FeO . SiO_2$	14	× 132						
$MgO . SiO_2$	387	× 100						
$FeO . SiO_2$	213	× 132	= Hypersthene	= 6,681				
$FeO . Fe_2O_3$	200	× 232	= Magnetite	= 4,640	M	9,200		
$FeO . TiO_2$	300	× 152	= Ilmenite	= 4,560				
$3 CaO . P_2O_5$	49	× 310	= Apatite	= 1,519	A	2,155		
FeS_2	53	× 120	= Pyrite	= 0,636				

$$\underset{\text{Dosalane}}{\frac{Sal}{Fem}} = \frac{79,71}{18,92} \underset{\text{Class II}}{<} \frac{7}{1} > \frac{5}{3}; \quad \underset{\text{Dosalone}}{\frac{QFL}{CZ}} > \frac{7}{1} \underset{\text{Subclass 1}}{;} \quad \underset{\text{Germanare}}{\frac{Q}{F}} = \frac{7,85}{71,64} \underset{\text{Order 5}}{<} \frac{1}{7}; \quad \underset{\text{Hessase}}{\frac{K_2O + Na_2O}{CaO}} = \frac{0,045}{0,192} \underset{\text{Rang 4}}{<} \frac{3}{5} > \frac{1}{7}; \quad \underset{\text{Hessose}}{\frac{K_2O}{Na_2O}} = \frac{11}{34} \underset{\text{Subrang 3}}{<} \frac{3}{5}$$

Osann's Classification.

s = 58,21 n = 7,54
A = 3,09 a = 2,29
C = 11,75 c = 8,72 k = 1,08
F = 12,11 f = 8,99

Monzonitic rocks.

These rocks occupy large regions of the Post-Jotnian areas. I have specially studied them in Ulfön and the islets in the neighbourhood, but they occur here and there in the islands to the north-east of Ulfön (Ellön consists almost entirely of such rocks), and in several localities in the region of Näske-fjärden. LUNDBOHM[1] says that »in the region north of Måbergsviken, in a hill called Hängsten, occurs a remarkable rock. It is a medium-grained, reddish rock, containing red feldspar and hornblende. Macroscopically it resembles a syenite or gabbro, but it occurs very intimately connected with the diabase, and for this reason it has not been distinguished from the latter. The same rock appears at Ellön, and the same variety has been observed at Germundsön, at the entrance to Gaviksfjärden. In the region of Hängsten it shows a beautiful banded texture, caused by alternate fine- and coarse-grained bands of different colours, of the thickness of 20 to 30 cm. Even at Ellön such a texture has been observed, and there the rock is connected by transition-forms with a greenish-black variety, with much olivine and of a granitic texture. This variety appears also in the eastern region of Trysundaön, east of Björnviken, and there passes over into the common rock of the Åsby-type. The reddish rock in question might be considered to be a modification of the common diabase».

It is only the larger regions of monzonitic rocks — and those which I have specially studied myself — that are indicated on the map.

These rocks are of very variable composition. They range from relatively acid varieties composed of alcalic feldspars, augite and magnetite — which may be classed among the syenites — to those of kentallenitic composition; these kentallenitic rocks being connected by transition-forms with the diabase. It may be stated that there is a great difference between these kentallenitic rocks and the kentallenite from Kentallen, which lies in the circumstance that the former contain more iron and much less magnesia than the latter. This depends upon the composition of the olivine, which in the Ulfö rocks referred to is rich in iron and poor in magnesia.

The rock in Korsberget consists of *plagioclase, orthoclase, augite, olivine, biotite, magnetite* and *apatite,* as primary constituents, and the common secondary products of these minerals, especially *hornblende.*

As is shown by the analysis, the feldspars constitute more than half of the rock.

The *plagioclases* are zonally built. In the rock analysed I have generally observed that the average composition is that of oligoclase-andesine, $Ab_{69}An_{31}$; but this is very variable; in some varieties the zonal structure is very marked, the kernel being labradorite, with an extinction of about — 20° on (010), and the periphery oligoclase-andesine. In

[1] Berggrunden inom Vesternorrlands län, p. 21.

TABLE VI.

Andose (Kentallenite) Korsberget, N. Ulfön. — (Analyst, N. Sahlbom).

	Per cent	Mol.	Mol. per cent
H_2O (below 110°) . .	0,36	—	—
H_2O (above 110°) . .	1,00	—	—
SiO_2	47,87	0,7978	53,08
TiO_2	1,51	0,0189	1,26
Al_2O_3	13,95	0,1368	9,10
Fe_2O_3	2,86	0,0179	—
FeO	12,90	0,1792	14,31
MnO	0,32	0,0045	0,30
CaO	7,60	0,1357	9,03
MgO	2,83	0,0707	4,70
K_2O	2,21	0,0235	1,56
Na_2O	4,80	0,0774	5,15
P_2O_5	1,96	0,0138	0,92
S	0,10	0,0031	0,20
Cl	0,21	0,0059	0,39
CO_2	0,00	—	—
BaO	traces	—	—
	100,48		
— O for Cl	0,09		
	100,39		

Quantitative Classification.

Formula	Mol.	Wt.		Norm				
$K_2O . Al_2O_3 . 6 SiO_2$	235	× 556	= Orthoclase	= 13,066	F	63,604	Sal	63,604
$Na_2O . Al_2O_3 . 6 SiO_2$	774	× 524	= Albite	= 40,558				
$CaO . Al_2O_3 . 2 SiO_2$	359	× 278	= Anorthite	= 9,980				
$CaO . SiO_2$	538	× 116						
$MgO . SiO_2$	176	× 100	= Diopside	= 12,779	P+O	15,162	Fem	35,221
$FeO . SiO_2$	362	× 132						
$2 MgO . SiO_2$	84	× 70	= Olivine	= 2,383				
$2 FeO . SiO_2$	176	× 102						
FeO	916	× 72	= (Mg, Fe) O	= 8,383	M	15,409		
MgO	447	× 40						
$FeO . Fe_2O_3$	179	× 232	= Magnetite	= 4,153				
$FeO . TiO_2$	189	× 152	= Ilmenite	= 2,873				
$3 CaO . P_2O_5$	138	× 310	= Apatite	= 4,278	A	4,650		
FeS_2	31	× 120	= Pyrite	= 0,372				

Class II	Order 5	Rang 3	Subrang 4
$\frac{Sal}{Fem} = \frac{63,60}{35,22} < \frac{7}{1} > \frac{5}{3}$	$\frac{F}{Q} = \frac{63,60}{0,00} > \frac{7}{1}$	$\frac{K_2O + Na_2O}{CaO} = \frac{1009}{1357} < \frac{5}{3} > \frac{3}{5}$	$\frac{K_2O}{Na_2O} = \frac{235}{774} < \frac{3}{5} > \frac{1}{7}$
Dosalane	Germanare	Andase	Andose

Osann's Classification.

s = 55,26 n = 7,68
A = 6,71 a = 3,83 k = 0,78
C = 2,39 c = 1,36
F = 25,95 f = 14,81

those varieties with more basic feldspar it is often observed that the kernel is altered. Accumulations of prehnite are then common. The plagioclase crystals are anhedral, and in this variety it has been one of the last minerals to separate. But, as soon as they become more calcic, their outlines appear more regular. The areas of their sections vary between 2 and 4 mm.^{2}

The *orthoclase* is recognised by its reddish colour, and is generally so turbid that it is nearly impossible to make any observation as to its extinction. It has been the last mineral to crystallise and generally surrounds the plagioclase.

The *augite* is the same variety as that occurring in the common diabase. Pleochroism is noticeable. The absorption formula is Y = light violet-gray > Z = X = about the same colour as Y, but fainter and containing a yellowish shade. The sections of the augite crystals have an average area of about 2 mm.^{2} Very often it is observed that the augite crystals contain inclusions of small flakes of biotite, which show the same orientation with each other. Inclusions of apatite and titaniferous magnetite are very common. It sometimes happens that several augite crystals occur implicated with each other.

The *olivine* is a variety rich in iron and is light brownish-yellow in colour. The crystals are always anhedral. Crystals with sections of 4 mm.^{2} are not rare, but the average area is about 2 mm.^{2} The cleavage parallel to (010) is very distinct, but that parallel to (100) is rather indistinct. The dispersion is strong, $\rho > \upsilon$. The angle of the optic axes is not so large as in chrysolite, and the sign is negative. I am inclined to think that it is either a fayalite or an olivine very rich in iron. It is generally very fresh, and, when altered, the decomposition-products are serpentine and magnetite. Inclusions of apatite and magnetite are common, the latter mineral being sometimes surrounded by biotite. Often sacciform inclusions of feldspar are observed in the olivine crystals.

Biotite. The absorption formula is Z = Y = dark brown > X = yellow, but by alteration it is transformed into a greenish variety with Z = = Y = dark grass-green > X = yellow. The sections of the crystals of this mineral are generally less than 1 mm.^{2} in area.

Magnetite and *Ilmenite*. They occur, for the most part, in anhedral crystals whose sections show irregular, sometimes rounded shapes of about 0,50 mm. in diameter. I have observed a hexagonal section of a euhedral crystal which I presume to be ilmenite. The iron-minerals occur as inclusions in all the other constituents, excepting apatite. Magnetite occurs also as a secondary product resulting from the alteration of the olivine.

Apatite is observed in relatively large quantities, and it has been the first mineral to separate. The greatest dimensions of the crystals are about 2 mm in the direction of the c-axis and 0,1 in a direction perpendicular to it, through the middle of the crystal.

Pyrrhotite and *pyrite* occur sparsely in small irregular grains.

Hornblende occurs in brown and green varieties, but, as it seems, only

as an alteration-product of the pyroxene. Besides this, there occur accumulations of actinolite, serpentine and magnetite, as decomposition-products of the olivine. This is confirmed by the existence of relics of olivine among the minerals in question. Both the varieties of common hornblende pass over into each other by means of transitions. The order of crystallisation has been apatite, magnetite with biotite, olivine, augite, plagioclase, orthoclase.

As has been stated, these rocks vary in composition, but all the varieties are free from quartz. This is the most important difference between these monzonites and the Post-Jotnian monzonites of Alviken, south of Köpmanholmen.

In the region of Skagsudden (S. Ulfön) there occurs a variety rich in augite. This mineral appears here in subhedral and anhedral crystals, generally twinned, the twinning plane being parallel to (100). The augite crystals are elongated in the direction of the c-axis. This variety contains very small quantities of olivine. The order of crystallisation appears to have been:

Apatite,
Magnetite,
Augite,
Plagioclase.

I cannot tell with certainty the place occupied by the olivine in the order of crystallisation, but I believe that its separation took place after the crystallisation of the magnetite and augite. The augite crystals contain very small grains of magnetite, but they always show independent shapes when in contact with the larger magnetite crystals, the forms of the latter mineral conforming to those of the augite. Consequently it is reasonable to suppose that the augite crystallised before the separation of the bulk of the magnetite. This shows once more that the quantity of each mineral present in the solution is the most important factor for determining the order of separation. This rock is millimeter-grained, and the fabric is nearly equigranular.

Ellön, an island which lies about two kilometers to the east-northeast of Trysundaön, consists principally of monzonitic rocks which are very analogous to those described above. In some regions of the island the rocks are banded. Bands containing femic minerals in great amounts alternate with others in which the salic minerals preponderate. Just on the northern coast the banding is very striking, and there occur rocks chiefly consisting of augite and titaniferous magnetite. A pecularity of these rocks is the occurrence of apatite in small, but very numerous crystals.

The constituents of the rock are: *augite, titaniferous magnetite, biotite, plagioclase, orthoclase, olivine, apatite.* The order of crystallisation

has been apatite, magnetite, olivine, augite, plagioclase, orthoclase. The most interesting feature of this variety is that the pyroxene has separated very early, but it must be remembered that the plagioclases are more sodic than in the common diabase, and, moreover, that orthoclase occurs. The pyroxene has sometimes crystallised in nearly euhedral crystals.

The rock analysed (Table VI), like the olivine-monzonites or kentallenites, is characterized by the low proportion of SiO_2. The kentallenite of Kentallen quarry, west of Ballachulish, Scotland, shows nearly the same proportion of silica. The proportions of the alcalies CaO and Al_2O_3 are very similar in both rocks. As has been pointed out above, the difference between them consists in the proportion of iron and magnesia, and this depends upon the circumstance that the rock at Kentallen probably contains an olivine relatively rich in magnesia, and the olivine of the rock in Korsberget is very rich in iron and poor in Mg O. The composition of the Kentallenite of Kentallen quarry[1] is: $SiO_2 = 48{,}00$; $Al_2O_3 = 12{,}52$; $(Fe_2O_3 + FeO) = 8{,}74$; $MgO = 15{,}26$; $CaO = 7{,}94$; $Na_2O = 3{,}11$; $K_2O = 2{,}68$; $H_2O = 1{,}36$; $TiO_2 = 0{,}22$.

With increasing amounts of silica the rock of Korsberget passes into the monzonites, and with increasing amounts of silica and of K_2O into rocks of the syenitic types.

The monzonite of Korsudden. At Korsudden we find that the diabase becomes more and more fine-grained as we approach the shore. At the shore itself occurs a small region occupied by a medium-grained, reddish monzonitic rock, and by a fine-grained, spotted rock rich in quartz. These rocks sometimes appear in sharp contact with the diabase and with each other, but in some cases it looks as if they passed into each other. Acid veins, which appear to generate from the monzonitic rock, cross the other two. The monzonitic rock consists of *quartz, micro-perthite, plagioclase, augite, olivine, magnetite, biotite, apatite, pyrite, pyrrhotite,* and *hornblende.*

This rock is phanerocrystalline, millimeter-grained, and the fabric is seriate homeoid.

The *quartz* occurs only in graphic implication with microperthite and plagioclase.

The *plagioclase* occurs in zonally built crystals. The kernels show an extinction angle on (010) of about 0°, and at the periphery an extinction angle of 11°. The most calcic kernel observed is $Ab_{72}\,An_{28}$ and the most sodic peripherical zone $Ab_{85}\,An_{15}$. The sections parallel to (010) show an area of between 2 and 4 mm^2. The plagioclase is sometimes graphically implicated with quartz in the peripherical regions of the crystals. Sometimes occur graphic implications between augite and the most calcic plagioclases, and between the last-named minerals and magnetite. The plagioclases have generally crystallised with irregular outlines, toothing with each other, but there are crystals with subhedral shapes.

[1] Rosenbusch, Elemente der Gesteinlehre p. 123.

Orthoclase and *micro-perthite* occur in irregular crystals of about the same dimensions as the plagioclases, and they are generally implicated with quartz. They generally surround the plagioclase crystals.

The *augite* appears to be about the same variety as that mentioned in connection with the description of the diabase. The colour is paler. Its birefringence is about 0,0251. The dispersion is weak, $\rho > \upsilon$. Pleochroism is nearly absent. Twinning is not common; in a twinned crystal the twinning plane appears to be parallel to (001). This mineral occurs in independent crystals and in graphic implication with plagioclase. The augite is altered into hornblende.

Olivine. The sign is negative, the angle of the optic axes appears to be relatively small, and the birefringence is about 0,048. The dispersion is $\rho > \upsilon$. Hence it must be a fayalite. The crystals always appear in very irregular shapes, and the sections attain dimensions of 5 mm^2. Pleochroism is noticeable, and the absorption formula is Y = brownish-yellow > X = brownish-yellow > Z = yellow. It contains numerous inclusions of magnetite. The alteration-products are those generally found for this mineral.

Magnetite occurs in small, irregular grains, with sections attaining 0,12 mm^2. It occurs included in olivine, augite and feldspars, and sometimes graphically implicated with plagioclase.

Biotite. It is the common variety that occurs in these rocks. The absorption formula is Z = Y = dark brown and X = pale yellow. When altered to green biotite, Z and Y show a grass-green colour, and X a rather dark yellow. It has crystallised in irregular flakes, for the most part surrounding the magnetite.

Apatite occurs in numerous, but generally small crystals, which sometimes attain a length of 2 mm. with a maximum diameter of less than 0,1 mm. Some of these needle-like crystals show a sudden decrease in diameter near the ends, terminating in a very narrow cylinder.

Pyrite and *pyrrhotite* occur in small amount. Analysis shows that these rocks are monzonites, but of an uncommon mineralogical composition. A peculiarity is the occurrence of an olivine, which is probably fayalite, in considerable quantities.

The order of crystallisation of its components has been: first apatite, then magnetite began to separate, followed by olivine; then comes augite. The last part of the augite solidified contemporaneously with the kernels of the plagioclases, as well as with a part of the magnetite. After this separated the more sodic part of the plagioclases, at the same time as a part of the quartz, and lastly orthoclase, albite and the rest of the quartz simultaneously.

The analysis represents the mean composition of the rock. The difference between the extreme forms of the rock is not great, and they must be classed with the mean type of monzonites.

TABLE VII.

Tonalose (Fayalite-Monzonite). Korsudden. N. Ulfön. (Analyst, N. Sahlbom).

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	0,52	—	—
H_2O (above 105°) . .	0,90	—	—
SiO_2	56,64	0,9440	63,46
TiO_2	1,88	0,0235	1,58
Al_2O_3	12,84	0,1259	8,46
Fe_2O_3	4,06	0,0254	—
FeO	8,43	0,1171	11,29
MnO	0,15	0,0021	0,14
CaO	4,08	0,0729	4,90
BaO	0,10	0,0007	0,05
MgO	2,01	0,0502	3,38
H_2O	3,17	0,0337	2,27
Na_2O	3,74	0,0603	4,05
P_2O_5	0,89	0,0063	0,42
S	0,24	0,0075	—
CO_2	0,11	0,0025	—
	99,76		

Quantitative Classification.

Formula	Mol.	Wt.		Norm			
SiO_2	1795	× 60	= Quartz	= 10,770	Q	10,770	Sal 69,972
$K_2O . Al_2O_3 . 6 SiO_2$	337	× 556	= Orthoclase	= 18,737	F	59,202	
$Na_2O . Al_2O_3 . 6 SiO_2$	603	× 524	= Albite	= 31,597			
$CaO . Al_2O_3 . 2 SiO_2$	319	× 278	= Anorthite	= 8,868			
$CaO . SiO_2$	200	× 116					
$MgO . SiO_2$	86	× 100	= Diopside	= 4,685	P	16,118	Fem 28,436
$FeO . SiO_2$	114	× 132					
$MgO . SiO_2$	416	× 100					
$FeO\ SiO_2$	551	× 132	= Hypersthene	= 11,433			
$FeO . Fe_2O_3$	254	× 232	= Magnetite	= 5,893	H	M 9,465	
$FeO . TiO_2$	235	× 152	= Ilmenite	= 3,572	T		
$3 CaO . P_2O_5$	63	× 310	= Apatite	= 1,953	A	2,853	
FeS_2	75	× 120	= Pyrite	= 0,900			
			CO_2	= 0,110			
			H_2O	= 1,420			

Class II	Order 4	Rang 3	Subrang 4
$\frac{Sal}{Fem} = \frac{69,97}{28,44} < \frac{7}{1} > \frac{5}{3}$;	$\frac{F}{Q} = \frac{59,20}{10,77} < \frac{7}{1} > \frac{5}{3}$;	$\frac{K_2O + Na_2O}{CaO} = \frac{940}{729} < \frac{5}{3} > \frac{3}{5}$;	$\frac{K_2O}{Na_2O} = \frac{603}{337} < \frac{3}{5} > \frac{1}{7}$
Dosalane	Austrare	Tonalase	Tonalose

Osann's Classification.

s = 65,46 n = 6,11
A = 6,32 a = 4,85 k = 1,10
C = 2,12 c = 1,62
F = 17,64 f = 13,53

As has been stated above, this monzonite appears in contact with, and merges into two other rocks. One of them, a very fine-grained basic rock, is a contact facies of the common diabase. The *plagioclases* range in composition from labradorite to oligoclase-albite. *Quarz* and *orthoclase* occur sporadically. Augite of the same kind as that occurring in the diabase is observed, but not olivine. Brown and green hornblende, and biotite occur. In quantity *magnetite* comes after the plagioclases and augite, and it must be considered as one of the essential constituents of the rock. As accessory constituent occurs *apatite*.

The other rock is reddish, porphyritic and marked with grayish flecks. Chemically it is probably of the same composition as the adamellites.

The porphyritic crystals are plagioclases, and their determination is impossible, because they are extremely altered. The rock consists of *orthoclase, plagioclase, quartz, hornblende, biotite, magnetite, apatite*.

The *orthoclase* is generally reddish-pigmented and occurs in graphic implication with quartz. Sometimes it is perthitic.

The *plagioclases* are oligoclase-albite and albite.

The *quartz* occurs in graphic implication with the feldspars, and in independent, rounded grains of about 1 mm. in diameter.

The *hornblende* occurs in great amount. Its absorption formula is Z = olive-green > Y = brownish-green > X = pale greenish-yellow. It generally appears in anhedral and subhedral crystals, but sometimes occur crystals of this mineral which are nearly euhedral. Twinning has been observed, the composition plane being parallel to (100).

Biotite occurs sparsely, and sometimes it appears surrounding magnetite.

Magnetite is common and is observed in anhedral and subhedral crystals.

Apatite is rather abundant, appearing in very slender crystals included in the other minerals.

In respect to the genesis of these rocks I can not offer any certain explanation. The field-observations support the supposition that very near the shore occurs granite, the contact between this rock and the diabase being submarine. As has been stated above, the diabase becomes fine-grained in Korsudden, and it is possible to observe all the transitions between this fine-grained, quartz-bearing facies and the coarse olivine-diabase some meters inland. I cannot find any other interpretation of the relations of the rocks at Korsudden than to suppose that fragments of the granite have been melted by the diabase, and in this way a heterogeneous mixture has been produced, which has solidified in the form of monzonitic rocks. The most acid products of the mixture cut the more basic rocks, which solidified earlier.

Monzonitic rocks occurring in dikes of lenticular form.

All the varieties of the diabase, and more especially the monzonitic rocks, are cut by lenticular dikes of a monzonitic constitution. These dikes are of a very heterogeneous composition. The analysis given in table VIII is from such a dike in the southern region of Norrsand (N. Ulfön). The dike is 15 m. in length, and its greatest breadth, 0,50 m., is in the middle. The analysis is of the most basic variety of the rock. It consists of *plagioclase, micro-perthite, pyroxene,* some *olivine, amphibole, mica, titaniferous magnetite,* and *apatite.*

The *plagioclase* is an oligoclase-andesine, because on (010) it shows an extinction angle of 0°. The crystals are relatively large, the sections cut according to (010) attaining a surface-area of about 16 mm^2. They are zonally built and their peripherical regions, which appear to consist of albite, are implicated with orthoclase, forming perthite.

The *micro-perthite* generally surrounds the plagioclase, and occurs in independent crystals of less dimensions than those of the plagioclase.

Pyroxene. — It is the same augite as occurs in the above-described Post-Jotnian rocks. It shows subhedral shapes and occurs here in large amounts. It is nearly always surrounded by hornblende. Sometimes it appears in greenish shades in the peripherical regions; but these greenish shades of the crystals appear to be caused by alteration, at least there is not observed any change in the optical properties of the augite, excepting those named. The crystals are somewhat elongated in the direction of the c-axis and their sections show an average surface-area of 4 mm^2.

Olivine occurs sparsely, and it is of the same kind as that occurring in the kentallenite of Korsberget. In one slice I observed a single section with an area of 0,50 mm^2.

Amphibole. — There occur two kinds of hornblende, a brown and a green variety. They both appear surrounding the augite and included in it, in a manner which leads one to consider them, at least in part, as alteration-products. Besides these varieties of amphibole there occur accumulations of actinolite.

Biotite occurs in relatively small flakes surrounding the titaniferous-magnetite. Very often it appears surrounding the amphibole, which, again, encloses the pyroxene.

Titaniferous magnetite. — This mineral occurs in rather large crystals surrounded by and implicated with biotite. The sections are generally very irregular and attain dimensions of about 4 mm^2.

Apatite appears relatively abundantly, in crystals extending over a wide range of magnitude. There occur crystals with a length of 3 mm. and some of a tenth of a millimeter.

The granularity of this rock is between centimeter-grained and millimeter-grained. The fabric approaches rather near to the seriate

TABLE VIII.

Shoshonose (Kentallenite). Southern region of Norrsand. N. Ulfö.
(Analyst, N. SAHLBOM.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	0,22	—	—
H_2O (above 105°) . .	1,01	—	—
SiO_2	48,84	0,8140	55,32
TiO_2	4,39	0,0549	3,73
Al_2O_3	13,83	0,1356	9,21
Fe_2O_3	2,92	0,0182	—
FeO	12,24	0,1700	14,02
MnO	0,22	0,0031	0,21
CaO	6,05	0,1080	7,34
MgO	2,18	0,0545	3,70
K_2O	3,59	0,0382	2,60
Na_2O	3,20	0,0516	3,51
P_2O_5	0,73	0,0051	0,35
S	0,15	0,0047	—
BaO	0,01	0,0001	0,01
	99,58		

Quantitative Classification.

Formula	Mol.	Wt.		Norm				
$K_2O . Al_2O_3 . 6\,SiO_2$	382	× 556	= Orthoclase	= 21,239				
$Na_2O . Al_2O_3 . 6\,SiO_2$	516	× 524	= Albite	= 27,038	F	61,009	Sal	61,009
$CaO . Al_2O_3 . 2\,SiO_2$	458	× 278	= Anorthite	= 12,732				
$CaO . SiO_2$	452	× 116						
$MgO . SiO_2$	163	× 100	= Diopside	= 10,701				
$FeO . SiO_2$	290	× 132						
$MgO . SiO_2$	284	× 100	= Hypersthene	= 9,506	P + O	22,760		
$FeO . SiO_2$	505	× 132						
$2\,MgO . SiO_2$	101	× 70	= Olivine	= 2,553				
$2\,FeO . SiO_2$	181	× 102						
$FeO . Fe_2O_3$	182	× 232	= Magnetite	= 4,222			Fem	37,472
$FeO . TiO_2$	549	× 152	= Ilmenite	= 8,345	M	12,567		
$3\,CaO . P_2O_5$	51	× 310	= Apatite	= 1,581				
FeS_2	47	× 120	= Pyrite	= 0,564	A	2,145		
H_2O				1,230				

Class II — Order 5 — Rang 3 — Subrang 3

$$\frac{Sal}{Fem} = \frac{68,01}{37,47} < \frac{7}{1} > \frac{5}{3}\ ; \quad \frac{Q}{F} = \frac{O}{61,01} < \frac{1}{7}\ ; \quad \frac{K_2O + Na_2O}{CaO} = \frac{898}{1080} < \frac{5}{3} > \frac{3}{5}\ ; \quad \frac{K_2O}{Na_2O} = \frac{382}{516} < \frac{5}{3} > \frac{3}{5}$$

Dosalane — Germanare — Andase — Shoshonose

Osann's Classification.

S = 59,40 n = 5,75
A = 6,11 a = 3,89
C = 3,10 c = 1,98 k = 0,91
F = 22,18 f = 14,13

porphyroid fabric. The analysis reveals a very large proportion of TiO_2, and, besides this, a general likeness to the Korsberget rock. The proportion of alkalies is somewhat higher in this rock, and the relation between Na_2O and K_2O somewhat different. For this reason the Korsberget rock is dosodic and that of Norrsand is sodi-potassic. Moreover, there are some other small differences — for instance, in the proportion of CaO. As a general observation it may be said that the Korsberget rock is somewhat more basic and richer in alkalis than the Norrsand rock. As has been mentioned above, the chemical difference between these rocks and the kentallenite from Kentallen lies in the amounts of iron and magnesia: the Ulfön rocks are rich in iron and poor in magnesia. The rock described from the lenticular dike of Norrsand merges into others richer in alkali feldspars and poorer in ferro-magnesian minerals, which very probably have a syenitic constitution. In the small islets east of N. Ulfön, and in other localities as well, occur analogous rocks in the form of streaks (Schlieren).

In the diabase occur dikes of a coarse-grained rock composed of the same minerals as the country-rock, and perhaps they are of the same chemical constitution. The principal difference between this rock and the common diabase lies in the dimensions of the minerals. The plagioclases are tabular and sometimes occur several centimeters in length. Generally they are sinuous and relatively short. They may perhaps be considered as kinds of pegmatites. Graphic implication is common between certain minerals; for instance, between augite and magnetite. They are probably contemporaneous dikes intruded immediately after the solidification of the diabase. These dikes are sometimes — and specially when cutting the monzonites, — orthoclase-bearing in a high degree, and then they show a monzonitic constitution. Sometimes the same coarse kind of rock is observed, not in the form of dikes, but as kinds of inclusions.

In the monzonitic regions occur fragmentary inclusions of rocks which show a more acid constitution, and are composed chiefly of alkalic feldspars.

The sequence of crystallisation.

As has been stated above, the order of crystallisation of the constituents in the Post-Jotnian rocks depends on the amounts of each of them present in the rock, or perhaps, more properly, in the solution. We have seen that, in the titaniferous iron-ore, it is the titaniferous magnetite that separates first. In the peridotitic rocks the olivine is the first mineral to crystallise and in the anorthositic varieties the plagioclase solidifies before the other minerals. In the rocks rich in augite this mineral crystallises early, and appears showing crystallographic faces, but it is not right to compare this case with the above-mentioned, because in the rocks rich in

augite the plagioclases are more sodic than in the peridotites, iron-ore and anorthosites.

My observations are in accord with the results obtained by M. J. MOROZEWICZ, W. MEYERHOFFER and J. H. L. VOGT. MOROZEWICZ, as is well-known, made classical experiments on the artificial production of minerals and rocks by fusion in a Siemens gas-furnace.[1] He writes: »Was den Process der Krystallisation selbst, d. h. die Reihenfolge der Mineralausscheidung aus dem Magma anlangt, so konnten wir uns wiederholt überzeugen, dass sie nicht von irgend einem Factor allein abhängt, z. B. von der »Schmelzbarkeit» (FOUQUÉ und M. LÉVY) oder von der »Acidität» der Silicate (ROSENBUSCH), sondern als das Resultat einiger zusammenwirkenden Momente, unter welchen einer von den wichtigsten ist — *das Verhältnis zwischen den Quantiteten der in der Lösung vorhandenen Verbindungen.* Eine und dieselbe Verbindung kann sich bei identischen Bedingungen früher oder später als eine andere (wir sprechen vom Beginn der Krystallisation) ausscheiden, gemäss ihrer Menge. Da diese Verhältnisse in verschiedenen Magmen grossen Schwankungen unterworfen sind un da diese *Magmen* eine sehr complicirte Silicatlösung darstellen, so muss begreflicherweise *die Krystallisationsfolge der Minerale,* allgemein gesagt, *in verschiedenen Magmen — verschieden sein.*»

MEYERHOFFER[2] writes: »Massgebend für die Reihenfolge der Ausscheidung sind also nicht die Schmelztemperaturen, sondern die Zusammensetzung der Schmelze, verglichen mit der des eutectischen Gemisches.»

VOGT,[3] in a series of remarkable publications, has treated the subject in detail in the light of modern physical chemistry. He had already in the year 1884, in his work »Studien über Schlacken» (Teil I, S. 2), expressed the opinion that the mass action is determinative for the separation of minerals.

That the acidity of the constituents plays an important rôle in the order of crystallisation is shown by the fact that, in those Post-Jotnian rocks where the plagioclases were relatively rich in sodium, the augite crystallised earlier than these minerals; but when the plagioclases were rich in calcium, and the augite occurred in about the same amounts as in the first case, it separated last.

In the Ulfö-diabase and its varieties the first mineral to separate is always that which occurs in excess of a certain fixed proportion between the minerals. See Plate VI, Fig. 1 and Plates VII, VIII and IX.

[1] Experimentelle Untersuchungen über die Bildung der Minerale im Magma. Tscher. Min. und Petr. Mittheilungen. 1899. p. 105.

[2] »Schmelzpunkte und Ausscheidungsfolge von Mineralien» in Zeitschr. für Kristallographie und Min. Bd. 36. 1902, p. 593.

[3] »Die Silicatschmelzlösungen» I and II. — »Physikalisch-chemische Gesetze der Krystallisationsfolge in Eruptivgesteinen» in Tschermarks Min. und Petr. Mitt. Bd 24, 25 and 27; and other publications.

The relations between the Sub-Jotnian and the Post-Jotnian rocks on Ulföarna.

General Remarks.

The contacts between the Sub-Jotnian granite and the diabase on Ulföarna is exposed in many places along the contact region. It generally follows a depression of the ground and is hidden by diabase blocks. The depression is usually only some meters in width, so that, if the topographical map is accurate, it is possible to lay down its configuration exactly.

In many cases it looks as if dislocations have taken place in the contact region. For instance, Fäbodsjön, in S. Ulfön, is limited on its eastern side by a very steep slope, which in its lower part is a nearly vertical wall. See Plate XII, Fig. 2.

The case of Sörbysjön, in the northern island, is an analogous one. North of this lake and west of the school-house, the diabase reaches higher levels than the granite, and appears limited to the west by a steep escarpment, occurring in a manner very similar to when it lies over sandstone. At Vårdkasberget the granite occurs at higher levels than the diabase hill close to it on the east, but south of Sandviken the diabase is superimposed on the granite again.

Age relations between the granite and diabase. — In his monograph,[1] LUNDBOM writes as follows: »Opportunities of studying the contacts between the olivine-diabase and the red granite have seldom presented themselves. But on Ulföarne this has been possible. About NW of the inner part of Långviken, on the east coast of S. Ulfön, there is an occurrence of granite in diabase of 4 to 5 m. in width. The diabase is aphanitic at the contact with the granite, but the granite shows its normal appearance. From the granite emanate many narrow veins, which cut the diabase. This rock contains small grains of granite. Analogous occurrences were observed at the limit between these rocks in the neighbourhood of Svartbergsviken, on the eastern coast of N. Ulfön; and, at a cape immediately to the south of the bay (Svartbergsviken), appear in the diabase narrow dikes of a red, medium-grained granite, which is like the common granite of this region. In other places in the neighbourhood occur interesting intermediate forms

[1] Berggrunden inom Vesternorrlands län. — p. 24.

between the rocks in question. To judge only from the relations observed in the field, it might doubtlessly be considered that the granites occurring in great bodies in this region are younger than the diabase, but as that supposition is at variance with other known facts it is necessary to seek another explanation of the contact features. The most obvious would be that the granite that occurs in veins is younger than that of the great bodies.»

When I first saw these occurrences I thought it was quite evident that the granites that form the great bodies were older than the diabase.

Along the contact-line it always happens that the diabase is aphanitic and its crystals increase in size as one retires from it. The granularity of the granite, on the contrary, is the same at the contact as at a distance from it. These features are sufficient to show that the granite must be older than the diabase.

Immediately to the north of Norrsand, at the shore, there are two small occurrences of granite-arkose, which are probably in connection with each other below the water. The southernmost occurrence appears over the sea, covering a surface of 60 m. in length and 20 m. in width. The other appears at 300 m. to the north, and shows a length of 16 m. and a breadth of 12 m. This arkose is identical with that occurring at Trysundaön as a substructure of the Jotnian quartzitic sandstone.

The diabase is aphanitic in the contact region, and becomes coarser the further one retires from it.

Consequently, the diabase is not only older than the granite, but even older than the granite-arkose.

On the southern slope of Hamnberget (N. Ulfön) occurs a rather large inclusion of quartzitic sandstone in the monzonite. It has a length of 150 m., a width of about 22 m., and a thickness of nearly 7 m.

The monzonite is sometimes fine-grained, but not always; it happens that it is coarse-grained at the contact, and not only rich in orthoclase, but also rich in quartz. The pyroxene is greenish, and it occurs even in the quartzite. Macroscopically the contact appears very sharp, but with the help of the microscope it is seen that the limit is not quite sharp. This quartzitic inclusion will, in all probability, belong to the Jotnian formation.

Consequently, we can say that on Ulfön it is perfectly plain that the diabase and its varietes are not only younger than the granite, but so much younger that a long denudation period separates them, because they are younger than the granite-arkose; and, moreover, it is manifest that the rocks in question are probably older than the Jotnian sandstone, because it is very probable that the inclusion at Hamnberget belongs to the Jotnian.

Granitic veins and inclusions in the diabase. — At Långviken (S. Ulfön) the contact is exposed in several places. Here can be observed

[1] J. M. Sobral, On the contact features of the Nordingrå Massive. Bull. of the Geol. Inst. of Uppsala. Vol IX. — 1910.

not only the chilled margin of the diabase, but even fragments of the granite enclaved in the fine-grained diabase of the contact.

The included fragments are of varying sizes. Some are small, others show sections of several square meters. From these granitic enclosures proceed veins, which cut the micro-crystallinic diabase. Their directions are sometimes straight, and now and then they are sinuous. Their granularity is variable; sometimes they are relatively coarse, but at other times they are fine-grained. They are always of a reddish colour, like the granite of the fragments, and merge into the former rock. I have never seen such a vein cutting both diabase and enclave, or the body from which it originates, so that apparently they only cut the diabase.

Between Långviken and Ulfösundet the contact is generally hidden; the depression which occurs along the contact widens sometimes, and then it is occupied by peat-moss. The contacts to the south-west and north-west of Fäbodsjön are also hidden. On the northern island the most interesting places are the contact south of Sandviken and the region of Svartbergsviken.

Sandviken. — South of Sandviken the diabase of the contact region is crossed by a network of reddish veins, which have the appearance of originating from the main granitic body. Besides this, in some parts are observed occurrences of granite in the diabase of the contact which have the shape and external appearance of dikes. They are not, however, true dikes, but inclusions originating from the granite. Only with the help of the microscope is it possible to detect the metamorphical changes caused by the diabase magma. These consist principally of the occurrence of an extraordinarily fine-grained graphic implication of orthoclase and quartz, replacing the perthite crystals in their peripherical regions, so that the rock becomes somewhat porphyritic. When magnified 54 diameters this graphic implication has a mottled appearance, being divided into small regions with somewhat different orientations. Sometimes the small regions show a spherulitic fabric. It is only when magnified more than 200 diameters that their real nature is detected. There occur, moreover, very fine-grained accumulations of quartz and orthoclase which are not implicated, but they probably have a composition which approaches that of a eutectic mixture.

Here and there in the granitic inclusion, moreover, appear accumulations of iron minerals.

That these granitic inclusions sometimes appear in the shapes of dikes depends upon the facility with which granite-fragments are loosened along the jointing-planes, owing to which very thin flakes with relatively large surfaces can be separated. This is interesting, because it shows that an occurrence of the shape of a dike is not always a real dike. This feature may be of importance for the interpretation of the age-relations in regions composed of dynamo-metamorphical rocks, where perhaps it is

not so easy, at least in many cases, to detect whether a particular occurrence is a dike or (as here) an enclave.

From the fragments, and even from the granitic body, emanate reddish veins, which consist of a eutectic mixture of *micro-perthite* and *quartz* and of *pyroxene; magnetite* and *hornblende* occurring as accessory minerals, the latter being very rare.

The graphic implication between micro-perthite and quartz is very fine-grained.

The *pyroxene* is not generally evenly distributed throughout the vein-rock. It generally appears along the contact with the diabase and evenly distributed in the vein in its narrowest parts. When an olivine phenocryst of the diabase comes into contact with the vein it is always surrounded by pyroxene, which does not happen in the case of the plagioclase. The sections of pyroxene are most frequently rounded, appearing with diameters of about 0,075 mm. The colour is greenish and the variety monoclinic. There occur basal-sections of this mineral that are quite euhedral. It appears to be the same variety of pyroxene as that which occurs in the sandstone inclusion at Hamnberget.

Magnetite appears in smaller crystals than the pyroxene, but not in such great amount. It has been the first mineral to separate.

Hornblende occurs sparsely; it is the same green variety as that occurring in the Sub-Jotnian granite, and its crystals are very irregular.

The order of crystallisation of the most important minerals is: magnetite, pyroxene, a eutectic mixture of microperthite and quartz. The vein described has a width of about 2 mm. It happens that two veins of this kind are connected by another, which has a breadth of only 0,15 mm.

In all the cases studied the veins merge into the granitic fragment or into the granitic body. This is explained by the fact that the constituents of the granite have been partially melted in the diabase, but the pyroxene and magnetite of the veins probably originate from the diabase. The diabase is always micro-crystallinic and porphyritic. The phenocrysts are olivine and zonally built plagioclases, and the rock contains much mica and magnetite.

Analogous phenomena are observed in the contact region between Sörsand and Svartbergsviken.

Consequently, my interpretation of those features is that the dike-shaped and fragmentary occurrences of granite in the diabase are fragments detached from the Sub-Jotnian granitic bodies by the Post-Jotnian diabase. The micro-pegmatitic veins which emanate from the fragments and from the granitic bodies at the contacts with the diabase are the consequence of the melting of the granite by the diabase.[1] Besides the described metamorphical changes caused by the diabase magma in the

[1] J. M. Sobral, »On the contact features of the Nordingrå Massive». Bull. of the Geol. instit. of Upsala, Vol. X, 1910.

granite, there occurs an invasion of the granitic region near the contact by minerals which are quite exotic for this rock.

Some very small grains of the greenish pyroxene mentioned above occur, and, moreover, there appear some crystals altered into a lamellar serpentinic mineral, which appears to be the alteration-product of some olivinic mineral.

The diabase at the contacts with the granite is always aphanitic. With the help of the microscope it is observed that its texture is porphyritic. The phenocrysts are of plagioclase and olivine. Generally along the contact line there occurs a zone of the width of 5 or 10 mm., where the phenocrysts are relatively large. At 5 or 10 mm. from the contact the size of the phenocrysts suddenly diminishes. The difference in size between the phenocrysts and the groundmass is, consequently, greatest at the contact. I have not observed glass in the groundmass of the diabase. This zone is what I call a *metastable zone*.

The relations between the plagioclase and olivine phenocrysts are variable, as a consequence of the variations in the composition of the diabase. Generally the olivine appears with somewhat more independent outlines than the plagioclases, but this perhaps depends upon the zonal structure of the plagioclases, which are more acid in the peripherical zone.

The *olivine* phenocrysts are generally elongated in a direction parallel to the axis c and attain a length of about 1 mm. They very often show concavities, which are generally interpreted as being the result of the solution of the crystals by the magma. They may be incomplete inclusions made by an irregularly growing crystal. IDDINGS[1] points out the analogy between the «bags» or pockets in the quartz of a glassy rhyolite and those existing in the quartz of a quartz-diorite, in the case of which latter there can be no question of solution.

The olivine phenocrysts are generally surrounded by a corona of biotite. The absorption formula of the biotite is Z = Y = dark reddish-brown, and X = whitish-yellow.

The olivine is generally fresh, but there occur grains completely altered into serpentine and into a reddish-brown mineral, somewhat pleochroic with low birefringence, which is probably a kind of serpentine.

The *plagioclase* phenocrysts are zonally built, and they do not show any noteworthy features.

The minerals of the *groundmass* are not determinable on account of their minuteness. In some regions we find that the groundmass occurs extinguished in mottles, as if its minerals had the same orientation over small areas.

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[1] Rock minerals. 1906. New York. p. 63.

Monzonitic rocks of Svartbergsviken.

In the northern region of Svartbergsviken (N. Ulfön), near the contact between the diabase and the granite, occur rocks of monzonitic composition. Near the shore and at about 26 m. from the contact there is an inclusion-like occurrence, the central part of which is composed of a reddish, medium-grained rock of granitic appearance. This occurrence becomes more basic towards the periphery in all directions, and it is connected by intermediate rocks with a variety of the common Ulfö-diabase. The occurrence is about 1 m. thick, its length is about 7 m. and its width 2 or 3 m. The rocks of which the occurrence is composed are intermediate forms between the diabase and granite, viz: adamellites, banatites, and monzonites. At about 15 m. to the NW and about 15 m. from the contact between the diabase and the granite there is another very analogous occurrence, which is also of adamellitic and granitic constitution in some regions and passes into basic rocks progressively.

I can come to no other conclusion than that these occurrences are detached fragments of the granite, melted by the diabase magma. In the first-named fragment there are not the least traces of the rock in its primary composition. The whole fragment has been violently metamorphosed and the resultant forms consist of mixed rocks only.

The second fragment, which lies nearer the contact and is larger (19 m. in length, 1,80 m. in thickness and 3 m. in width), has been less metamorphosed. Some regions of it appear to be very little mixed, but they are fine-grained, so that at least they have been re-fused.

Adamellite.

The most acid rock of the first fragment consists principally of *quartz, micro-perthite plagioclase, hornblende* and *biotite;* as accessory minerals appear *magnetite,* and *apatite,* the latter in very small proportions.

The *quartz* appears in relatively large, rounded grains, showing sections with a diameter of about 0,50 mm., and implicated with feldspar.

The *micro-perthite* appears in irregular grains, with sections which, on the average, are below 0,50 mm.^{2} in area. The orthoclase of the micro-perthite is nearly always reddish-pigmented.

The *plagioclase* is an oligoclase-albite $Ab_{85}An_{15}$; it occurs in irregular grains, which are generally stalky and appear in a kind of interposition with quartz. Between the elongated plagioclase crystals appears quartz, also in scapiform crystals, or in many small crystals with the same orientation.

The *hornblende* is the mineral that appears in the largest crystals. They are always scapiform, the sections sometimes attaining a length of 7 mm. and a width of 0,2 mm. The greater part of the hornblende crystals are turbid in the central regions and several of them contain relics of pyroxene in the kernel. The hornblende is a greenish-brown to brown variety. The absorption formula is Z = green > Y = brownish-green > X = clear yellow.

The *biotite* appears in small, irregular flakes, sometimes surrounding hornblende. Its sections are about 0,20 mm.^{2} in area.

Magnetite occurs in rods and in subhedral and anhedral equant crystals, included in all the other minerals excepting apatite. The length of the rods is about 0,20 mm. and their width 0,005 mm. The equant crystals show a diameter of about 0,09 mm.

The colour of the rock is reddish, with grayish spots. The reddish parts show a granitic texture and composition. The grayish flecks consist of a very fine-grained micrographic implication, which sometimes shows a spherulitic and radiating fabric. The implication is between quartz and alkali-feldspar. I am inclined to think that the feldspar is orthoclase; the implication is so fine-grained that a definite determination of the feldspar is not possible. The pigmentation of the feldspar is very slight, and for this reason the mottles are of a gray colour.

The order of separation of the minerals has been apatite, magnetite, pyroxene, hornblende, plagioclase, plagioclase and some quartz, micro-perthite, orthoclase and quartz. The last consolidation-product is a graphic implication between alkali-feldspar and quartz, and plays an analogous rôle to the groundmass in porphyritic rocks. We have consequently that first separated the part of the magma which is in excess of the eutectic proportions, and finally, as a kind of groundmass, a very fine-grained implication of feldspar and quartz in eutectic mixture. It seems that BECKER was the first to point out that the groundmass in porphyritic rocks tends to a eutectic composition. In a paper on «The Geology of the Philippine Islands»[1] he remarks that «if a labradorite-basalt is conceived as a eutectic mixture, capable, at sufficiently high temperatures, of dissolving more feldspar and olivine, it is easily conceivable that rocks of this class should be found containing many large feldspars or no feldspathic phenocrysts, much olivine or none at all, while the groundmass, representing the eutectic mixture, would maintain a nearly uniform composition and character, independent of the phenocrystic composition».

[1] U. S. Geol. Surv. Annual Report 1899—1900. Part III, p. 519.

TABLE IX.

Adamellose-Dacose (Adamellite). — Svartbergsviken (N. Ulfön).
(N. Sahlbom, analyst.)

	Per cent	Mol.	Mol. pr cent
H_2O (below 110°) . .	0,36		
H_2O (above 110°) . .	0,60	—	
SiO_2	69,19	1,1532	74,29
TiO_2	0,54	0,0067	0,43
Al_2O_3	11,86	0,1163	7,49
Fe_2O_3	1,22	0,0076	
FeO	4,72	0,0656	5,21
MnO	0,08	0,0011	0,07
CaO	2,45	0,0438	2,82
MgO	2,02	0,0505	3,25
K_2O	3,57	0,0380	2,45
Na_2O	3,80	0,0613	3,90
P_2O_5	0,10	0,0007	0,05
S	0,02	0,0006	
BaO	traces		—
	100,53		

Quantitative Classification.

Formula	Mol.	WT.		Norm.				
SiO_2	3963	× 60	= Quartz	= 23,778	Q	23,778	Sal	81,753
$K_2O . Al_2O_3 . 6\,SiO_2$	380	× 556	= Orthoclase	= 21,128	F	57,975		
$Na_2O . Al_2O_3 . 6\,SiO_2$	613	× 524	= Albite	= 32,121				
$CaO . Al_2O_3 . 2\,SiO_2$	170	× 278	= Anorthite	= 4,726				
$CaO . SiO_2$	245	× 116						
$MgO . SiO_2$	121	× 100	= Diopside	= 5,689	P	14,769	Fem	17,839
(Fe, Mn) O . SiO_2	124	× 132						
$MgO . SiO_2$	384	× 100	= Hypersthene	= 9,080				
(Fe, Mn) . SiO_2	397	× 132						
$FeO . Fe_2O_3$	76	× 232	= Magnetite	= 1,763	M	2,781		
$FeO . TiO_2$	67	× 152	= Ilmenite	= 1,018				
$3\,CaO . P_2O_5$	7	× 310	= Apatite	= 0,217	A	0,289		
FeS_2	6	× 120	= Pyrite	= 0,072				

Class	Order 4	Rang 2	Subrang 3
$\frac{Sal}{Fem} = \frac{81,8}{17,8} < \frac{7}{1} > \frac{5}{3}$	$\frac{F}{Q} = \frac{58,0}{23,8} > \frac{5}{3} < \frac{7}{1}$	$\frac{K_2O + Na_2O}{CaO} = \frac{993}{438} > \frac{5}{3} < \frac{7}{1}$	$\frac{K_2O}{Na_2O} = \frac{380}{613} < \frac{5}{3} > \frac{3}{5}$
Dosalane	Austrare	Dacase	Adamellose Dacose

Osann's Classification.

s = 74,77	n = 6,14		
A = 6,35	a = 6,79	k = 1,27	
C = 1,14	c = 1,22		
F = 11,21	f = 11,99		

VOGT in his work «Die Silikatschmelzlösungen, II («Über die Schmelzpunkt-Erniedrigung der Silicatschmelzlösungen»)[1], p. 175, observes that «In den relativ basischen Quartzporphyren und Rhyoliten (mit Pechsteinen, Quartzandesiten, Andesiten und Daciten), nämlich in denjenigen Gesteinen, die unterhalb etwa 70—73 % SiO_2 enthalten — die Grenze lässt sich nicht ganz scharf angeben, unter anderem weil sie von dem Verhältnis Or: Ab: An abhängig ist — ist das Erstarrungs-Endprodukt durchgängig SiO_2-reicher als das ursprüngliche Gesteinsmagma geworden, indem hier auf einem frühen Krystallisationsstadium immer relativ viel Feldspat ausgeschieden ist».

In the adamellite of Svartbergsviken the end-products of solidification are decidedly richer in silica than the part of the magma which separated first, and this is relatively rich in feldspars and quartz. The crystallisation of the last part of the magma is in part spherulitic and always very fine-grained, and probably it has crystallised from a very supersaturated magma. I have observed some acid veins cutting these fragments, which probably emanated from these acid end-products before they were so viscous as to be unable to penetrate the already crystallised parts of the rock-mass.

Banatites.

The adamellites pass into banatites by means of transitions rocks. The banatites consist of *quartz, orthoclase, plagioclase, monoclinic pyroxene, orthorhombic pyroxene, hornblende and biotite,* as essential constituents, and *magnetite, apatite* and *pyrite,* as accessory constituents.

The *quartz* generally appears in graphic implication with the feldspars, but here and there occur crystals which have separated independently. This phenomenon is perhaps only apparent and probably all the quartz is associated with the feldspars in a eutectic mixture.

Plagioclase. This mineral appears in zonally built crystals, whose composition ranges from Andesine, $Ab_{62}An_{38}$, to albite, and they are generally surrounded by orthoclase. Some crystals are implicated with orthoclase and quartz, the implication of orthoclase and quartz occupying the kernel and being in communication with the same implication as surrounds the plagioclase crystal. The areas of the sections vary between 1 and 3 mm.[2]

The *orthoclase* nearly always occurs in graphic intergrowth with quartz and plagioclase.

The *orthorhombic pyroxene* is hypersthene. It occurs in elongated crystals, generally surrounded by the other ferro-magnesian minerals, and is the essential constituent which has crystallised first.

[1] Skrifter udgivne af Videnskabs-Selskabet i Christiania 1904. I. Mathematisk-Naturvidenskabelig Klasse. — Christiania 1905.

The *monoclinic pyroxene* is augite. It has crystallised after the hypersthene and sometimes appears in graphic implication with plagioclase. It surrounds hypersthene and is surrounded by hornblende and biotite.

Hornblende appears surrounding pyroxene and in graphic implication with plagioclase, orthoclase and quartz, consequently forming a quaternary eutectic. I do not know if this hornblende of the graphic implication is primary, or if it is an alteration-product of augite: it is of the common greenish-brown variety. Sometimes the implicated hornblende has crystallised about a centre, presenting a radiating arrangement, and the different parts of the implication do not show the same extinction. They become dark successively as in spherulitic aggregations.

Biotite occurs in small amounts.

Magnetite appears in very small anhedral grains, included in the feldspars, quartz and ferromagnesian minerals, sometimes surrounded by biotite.

Apatite appears in very small acicular crystals, but very sparingly.

All the ferro-magnesian minerals generally occur in juxtaposition. The orthorhombic pyroxene is surrounded by the monoclinic in concentric, parallel growth; then comes hornblende and lastly mica.

This rock is millimeter-grained and the predominant fabric is the graphic.

Monzonite.

This rock consists of *quartz, orthoclase, plagioclase, monoclinic* and *orthorhombic pyroxene, hornblende, mica, magnetite* and *apatite.*

The *quartz* always occurs in graphic implication with orthoclase as the last solidification-product.

The *orthoclase* occurs in relatively large amounts (about 20%). It is in part implaced with quartz and the rest occurs surrounding plagioclase. The orthoclase is reddish-pigmented.

The *plagioclases* are zonally built and their composition ranges from labradorite, Ab_{42} An_{58}, to oligoclase-albite. They are generally somewhat tabular, parallel to (010), and show sections with areas of between 2 and 3 mm^2. There occur plagioclases with a length of 10 mm.; and sometimes they occur in divergent aggregations; the spaces between the plagioclase crystals being filled by orthoclase.

Orthorhombic pyroxene. — Pleochroism is distinct. The absorption formula is X = pale reddish-yellow > Y = pale yellow > Z = pale yellow. The negative acute bisectrix is perpendicular to (100) and the dispersion is distinct $\rho > \upsilon$. In vertical sections the extinction is always parallel, so it must be a hyperstene. The hypersthene has been the first of the ferro-magnesian minerals, to separate. It occurs in elongated, acicular forms according to the c-axis, sometimes in branching crystals. Some of

TABLE X.

Andose-Shoshonose (Monzonite). Svartbergsviken (N. Ulfön).
(Analyst, N. Sahlbom.)

	Per cent	Mol.	Mol. per cent.
H_2O (below 105°) . .	0,30		
H_2O (above 105°) . .	0,56		
SiO_2	57,21	0,9535	62,463
TiO_2	0,69	0,0086	0,563
Al_2O_3	16,03	0,1572	10,298
Fe_2O_3	1,65	0,0103	—
FeO	7,38	0,1025	8,064
MnO	0,18	0,0025	0,164
CaO	5,18	0,0925	6,060
MgO	3,36	0,0840	5,503
K_2O	3,50	0,0372	2,437
Na_2O	4,12	0,0665	4,356
P_2O_5	0,20	0,0014	0,092
S	0,10	0,0031	—
BaO	traces	—	
	100,46		

Quantitative Classifikation.

Formula	Mol.	WT.	Norm.			
SiO_2	215 × 60	= Quartz	= 1,290	Q	1,290	Sal 71,692
$K_2O . Al_2O_3 . 6\,SiO_2$	372 × 556	= Orthoclase	= 20,683	F	70,402	
$Na_2O . Al_2O_3 . 6\,SiO_2$	665 × 524	= Albite	= 34,846			
$CaO . Al_2O_3 . 2\,SiO_2$	535 × 278	= Anorthite	= 14,873			
$CaO . SiO_2$	343 × 116					
$MgO . SiO_2$	171 × 100	= Diopside	= 7,959	P	23,533	Fem 28,036
$FeO . SiO_2$	172 × 132					
$MgO . SiO_2$	669 × 100	= Hypersthene	= 15,574			
$FeO . SiO_2$	673 × 132					
$FeO . Fe_2O_3$	103 × 232	= Magnetite	= 2,390	M	3,697	
$FeO . TiO_2$	86 × 152	= Ilmenite	= 1,307			
$3\,CaO . P_2O_5$	14 × 310	= Apatite	= 0,434	A	0,806	
FeS_2	31 × 120	= Pyrite	= 0,372			

Class II — Order 5 — Rang 3 — Subrang 4

$$\frac{Sal}{Fem} = \frac{71,7}{28,0} < \frac{7}{1} > \frac{5}{3}; \quad \frac{F}{Q} = \frac{70,4}{1,3} > \frac{7}{1}; \quad \frac{K_2O+Na_2O}{CaO} = \frac{1037}{925} < \frac{5}{3} > \frac{3}{5}; \quad \frac{K_2O}{Na_2O} = \frac{372}{665} < \frac{3}{5} > \frac{1}{2}$$

Dosolane — Germanare — Andase — Andose Shoshonose

Osann's Classification.

s = 63,12 n = 6,41
A = 6,79 a = 5,11 k = 0,99
C = 3,51 c = 2,64
F = 16,29 f = 12,25

these crystals may attain 12 mm. in length with a diameter of only 0,30 mm. For the greater part of their length the crystals are generally nearly straight, but near the extremities they are split, and the crystal is prolonged in several directions. Sometimes it appears as if there were successive growths of several crystals attached to one another in somewhat inclined positions[1], so that the whole crystal shows a curved section. In most cases not only the kernel, but the greater part of each crystal consists of hypersthene, but the hypersthene is surrounded by a thin crust of augite, and this is overgrown here and there by hornblende. Whether this hornblende is of secondary origin or not I am not able to decide.

The *monoclinic pyroxene* appears to be an augite of the same kind as that occurring in the diabase, but paler. As has been mentioned above, it overgrows the hypersthene. It occurs implicated with plagioclase in radiating crystals, which are sometimes extinguished successively, but it happens that they show the same orientation.

Hornblende occurs surrounding the pyroxene and sometimes independently. This may perhaps be apparent, the cause of the seeming occurrence of independent crystals being that the section cuts the peripherical regions of the pyroxene crystal surrounded by hornblende. Its absorption formula is Z = dark olive-green > Y = dark brownish-green > X = clear brownish-yellow. It is sometimes surrounded by biotite.

The *biotite* is of the same kind as that occurring in all these rocks. It has an absorption formula X = Y = dark brown > X = clear yellow. It is implicated with and surrounds magnetite.

The *magnetite* occurs in anhedral crystals of small dimensions, whose sections are always below 0,20 mm^2. There occur interpositions of biotite, magnetite and pyroxene.

Apatite appears in very small amounts.

The order of crystallisation appears to have been apatite, magnetite and biotite, orthorhombic pyroxene, a part of the augite and magnetite, augite and plagioclase, orthoclase, and finally orthoclase and quartz.

The rock is millimeter-grained. There occur graphic and poikilitic fabrics between augite and plagioclase, and between augite and magnetite, and the radiating implications between augite and plagioclase form a kind of radial or spherulitic fabric.

Quartz-porphyry.

In the other fragment, which, as has been stated above, occurs nearer the contact (15 m. from the contact), the metamorphic effects of the diabase have not been so violent. The whole fragment has been brought to the fluid magma state, but there are parts of it which have not been mixed and have

[1] Iddings, Igneous Rocks. p. 224. — New York 1909.

TABLE XI.

Hessose-Auvergnose (olivine-diabase), Svartbergsviken (N. Ulfön).
(Analyst, N. Sahlbom.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	0,21	—	—
H_2O (above 105°) . .	0,51	—	—
SiO_2	45,82	0,7637	50,05
TiO_2	2,20	0,0275	1,80
Al_2O_3	17,34	0,1700	11,15
Fe_2O_3	1,70	0,0106	—
FeO	11,69	0,1624	12,04
MnO	0,22	0,0031	0,20
CaO	8,98	0,1604	10,51
MgO	5,81	0,1452	9,52
K_2O	1,42	0,0151	0,99
Na_2O	3,32	0,0535	3,51
P_2O_5	0,56	0,0039	0,20
S	traces	—	—
BaO	traces	—	—
	99,78		

Quantitative Classification.

Formula	Mol.	WT.		Norm.				
$K_2O . Al_2O_3 . 6 SiO_2$	151	× 556	= Orthoclase	= 8,396	F	64,619	Sal	64,62
$Na_2O . Al_2O_3 . 6 SiO_2$	535	× 524	= Albite	= 28,034				
$CaO . Al_2O_3 . 2 SiO_2$	1014	× 278	= Anorthite	= 28,189				
$CaO . SiO_2$	460	× 116						
$MgO . SiO_2$	245	× 100	= Diopside	= 10,624	P+O	20,358	Fem	34,36
$FeO . SiO_2$	215	× 132						
$2 MgO . SiO_2$	611	× 70	= Olivine	= 9,734				
$2 FeO . SiO_2$	535	× 102						
FeO	524	× 72	= (Mg, Fe)O	= 6,157	M	12,796		
MgO	596	× 40						
$FeO . Fe_2O_3$	106	× 232	= Magnetite	= 2,459				
$FeO . TiO_2$	275	× 152	= Ilmenite	= 4,180				
$3 CaO . P_2O_5$	39	× 310	= Apatite	= 1,209	A	1,209		

Class II	Order 5	Rang 4	Subrang 3
$\frac{Sal}{Fem} = \frac{64,6}{34,4} < \frac{7}{1} > \frac{5}{3}$;	$\frac{F}{Q} = \frac{64,6}{0} > \frac{7}{1}$;	$\frac{K_2O+Na_2O}{CaO} = \frac{686}{1604} < \frac{3}{5} > \frac{1}{7}$;	$\frac{K_2O}{Na_2O} = \frac{151}{535} < \frac{3}{5}$
Dosalane Salfemane	Germanare Gallare	Hessase Auvergnase	Hessose Auvergnose

Osann's Classification.

s = 52,05	n = 7,80		
A = 4,50	a = 2,45	k = 0,79	
C = 6,65	c = 3,62		
F = 25,62	f = 13,93		

crystallised as quartz-porphyry. This quartz-porphyry has very probably the same, or at least nearly the same, chemical composition as the Sub-Jotnian granite, because it consists of the same minerals apparently in the same proportions. It contains very small quantities of dark minerals, and the difference between it and the granite lies in the texture.

The *phenocrysts* are anhedral, somewhat rounded quartz crystals, which attain sectional dimensions of about 1 mm^2.

The *groundmass* has consolidated in two stages. After the separations of the phenocrysts, occurred the crystallisation of a part of the groundmass, consisting of a nearly eutectic mixture of micro-perthite and quartz, and finally the feldspar and quartz crystallised in a very fine-grained graphic implication, forming grayish, fine-grained mottles of the same nature as those mentioned in the description of the adamellite. The sections of the quartz and feldspars of the part of the groundmass which solidified first are about 0,10 mm^2. The sections of the quartz grains of the gray-coloured flecks are about 0,0002 mm^2 in area. There occurs some greenish *hornblende* in elongated crystals and, moreover, *titanite* in beautiful subhedral crystals, *calcite, magnetite* in small euhedral and subhedral crystals and *zircon.*

Consequently, there have been generated all the intermediate rocks between granite and diabase, by means of assimilation of granitic fragments by the diabase.

The rocks generated by this process of re-fusion and assimilation are: quartz-porphyries, adamellites, banatites and monzonites.

To determine how far was the influence of the assimilation of the fragments in the diabase magma extended I not only studied a series of slices, but let an analyst analyse a sample taken at a distance of about 12 m. to the south of the first fragment (that which lies at a greater distance from the contact). The analysis is that appearing in Table XI; and analysis of another sample taken at a distance of about 120 m. in the same direction appears in Table XII. Comparing these analyses with that of Table II, it is observed that the rocks have about the same quantity of SiO_2. The difference in Al_2O_3 is relatively great. The rock from the quarry west of Hamnberget is richer in ferro-magnesian minerals, and that explains why the analysis of this rock shows greater amounts of FeO and MgO than the samples from Svartbergsviken. The same circumstance explains why the rock of Table II shows lower figures for Na_2O; the rocks of Tables XI and XII, being more feldspathic, must contain greater amounts of Al_2O_3, Na_2O and even of CaO. The difference in K_2O is relatively slight. It appears to me that the analysed varieties of diabase from Svartbergsviken may be considered as uninfluenced by the assimilation of the granitic fragments, and, taking into consideration the great variability of the diabase, rocks analogous to those represented by Tables XI and XII may be found even in the neighbourhood of the quarry west of Hamnberget, from where the sample analysed in Table II was taken. Consequently

TABLE XII.

Hessose (Olivine-diabase). Svartbergsviken (N. Ulfön).
(N. Sahlbom, analyst.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	0,22	—	—
H_2O (above 105°) . .	0,81	—	—
SiO_2	45,85	0,7642	50,95
TiO_2	1,98	0,0247	11,65
Al_2O_3	18,43	0,1807	12,05
Fe_2O_3	1,76	0,0110	—
FeO	11,60	0,1611	12,21
MnO	0,22	0,0031	0,21
CaO	8,73	0,1559	10,39
MgO	4,67	0,1167	7,78
K_2O	1,34	0,0143	0,95
Na_2O	3,24	0,0523	3,49
P_2O_5	0,68	0,0048	0,32
S	0,07	0,0022	—
BaO	traces	—	—
	99,60		

Quantitative Classification.

Formula	Mol.	WT.		Norm.				
$K_2O . Al_2O_3 . 6\,SiO_2$	143	× 556	= Orthoclase	= 7,951	F	67,076	Sal	67,076
$Na_2O . Al_2O_3 . 6\,SiO_2$	523	× 524	= Albite	= 27,405				
$CaO . Al_2O_3 . 2\,SiO_2$	1141	× 278	= Anorthite	= 31,720				
$CaO . SiO_2$	280	× 116						
$MgO . SiO_2$	134	× 100	= Diopside	= 6,515	P+O	20,456	Fem	31,651
$FeO . SiO_2$	146	× 132						
$2\,MgO . SiO_2$	769	× 70	= Olivine	= 13,941				
$2\,FeO . SiO_2$	839	× 102						
(Fe, Mg)O	264	× 40	= (Fe, Mg)O	= 3,137				
	289	× 72						
$FeO . Fe_2O_3$	110	× 232	= Magnetite	= 2,552	M	9,443		
$FeO . TiO_2$	247	× 152	= Ilmenite	= 3,754				
$3\,CaO . P_2O_5$	48	× 310	= Apatite	= 1,488	A	1,752		
$Fe\,S_2$	22	× 120	= Pyrite	= 0,264				

Class II	Order 5	Rang 4	Subrang 3
$\frac{Sal}{Fem} = \frac{67,1}{31,7} < \frac{7}{1} > \frac{5}{3}$;	$\frac{F}{Q} = \frac{67,1}{0} > \frac{7}{1}$;	$\frac{K_2O + Na_2O}{CaO} = \frac{666}{1559} < \frac{3}{5} > \frac{1}{7}$;	$\frac{K_2O}{Na_2O} = \frac{143}{523} < \frac{3}{5}$
Dosalane	Germanare	Hessase	Hessose

Osann's Classification.

s = 52,92 n = 7,86
A = 4,44 a = 2,53 k = 0,96
C = 7,71 c = 4,30
F = 22,98 f = 13,08

I think that the influence of the first fragment may be considered to be limited to a zone not extending more than 12 m. from the fragment.

These occurrences are of importance for the geologist and petrologist, because they show that the power of assimilation of rock magmas may be great even at relatively slight depths below the earth's surface, in the same way as these processes have probably taken place, and because they show that mixed rocks are not always of a peculiar composition.

The adamellite of Svartbergsviken is chemically fairly similar to the adamellite of Brixen, Tyrol.[1] The monzonite from the former locality is of a composition analogous to that from Mulatto, Tyrol.[1]

The contact-metamorphism described from Svartbergsviken may be considered as a more advanced stage of that presented by the dike-shaped inclusions of Sandviken.

[1] BRÖGGER, Die triadische Eruptionsfolge bei Predazzo p. 62.

Basalt and diabase dikes.

Basalt dikes.

Basalt dike in the northern region of Norrsand. This dike crosses the diabase in the northern region of Norrsand.

To the naked eye the rock is, for the most part, black and porphyritic. The phenocrysts appear to be chiefly feldspars, and, because of their size, the rock is mediophyric. The groundmass is aphanitic.

In respect to the chemical composition of this rock I refer to what has been said on p. 94, where a rock very similar to this in composition is described. See Table XIII and Table II.

The rock is hypocrystalline. The relative amounts of crystalline and glassy components are:

$$\frac{\text{crystals}}{\text{glass}} < \frac{7}{1} > \frac{5}{3} = \text{docrystalline.}$$

The largest plagioclase phenocrysts are about 3,20 mm. in the direction of the edge (001) (010), the breadth on (010) is 0,32 mm., and on (001) 0,06 mm. The sectional dimensions of the largest olivine phenocrysts are about (2,8 × 1,7) mm^2. A close examination of the rock shows that there is no hiatus between the biggest porphyritic crystals and those of the groundmass.

The feldspar crystals of the groundmass are about 0,070 mm. in length and 0,008 mm. in breadth.

The rock is chiefly composed of crystals of different orders of magnitude, and, since the variation in size of the crystals is gradual from the phenocrysts to the crystals of the groundmass, the fabric is seriate porphyritic. See Plate X, fig. 1. The relative proportions of phenocrysts and groundmass are:

$$\frac{\text{g. m.}}{\text{ph.}} < \frac{7}{1} > \frac{5}{3} = \text{dopatic.}$$

As has been pointed out above, the porphyritic crystals are plagioclases and olivines.

The *feldspar phenocrysts* are basic plagioclases with subhedral and anhedral shapes. They show a zonal structure, sometimes very beautiful, especially in sections perpendicular to both (001) and (010). I shall describe a case which is characteristic. It is a section of the kind in question, with a surface of about $(0{,}120 \times 0{,}075)$ mm^2. The outlines are quite quadratic and no less than 16 zones are observable. The zones are alternately basic and acid, but the difference in chemical composition is relatively small. The outermost zone is the most acid (Ab_{45} An_{55}), and it is that which has a composition most divergent from the average. The basic zones are those which have the greater thickness, with the exception of the second zone from the centre, which is acid and relatively thick. The central part is a labradorite, Ab_{35} An_{65}. Those which I call basic zones are bytownites, with a composition of about Ab_{23} An_{77}. In sections parallel to (010) I have made determinations of plagioclases varying between the limits of these two varieties.

The feldspar phenocrysts are not always evenly distributed; there are accumulations of them, forming groups, in which sometimes occur olivine crystals. Very often I have observed inclusions of the groundmass in the feldspars. In these inclusions the crystals are smaller than those in the groundmass, but sometimes they are of equal size.

The *olivine phenocrysts* generally occur as subhedral crystals, but they may be anhedral. In contrast to the feldspars, which are generally very little altered, the olivine very often shows traces of decomposition. There are all the transitions in alteration to serpentine, from quite altered to quite fresh crystals. The alteration is accompanied by the separation of magnetite. The serpentine is probably antigorite. The optic angle is nearly 0°, with negative sign. The colour is green, of various shades, and brownish in the less altered regions of the crystal.

Evenly distributed in the serpentine mass of a very altered olivine crystal I have observed small accumulations of an opaque mineral, which may be magnetite. The mineral occurs in the form of rods, radiating from one point in the same manner as wheat or straw when tied in sheaves. The rods are about 0,080 mm. in length, and in the majority of cases their diameter is less than 0,001 mm.

The olivine is sometimes older than the plagioclases, but in some cases it is not. In some feldspathic accumulations big olivine crystals perform the same function as the groundmass, being crossed in all directions by the plagioclase phenocrysts, but there are cases in which the olivine shows more independent outlines than the plagioclases in contact with it. One gets the impression that the phenocrysts that crystallised first were the plagioclases, and before they finished their crystallisation the olivine solidified.

The same as has been said about groundmass-inclusions in the plagioclase phenocrysts can be applied to the olivine phenocrysts. It may be added that, in the case of the olivine phenocrysts, the inclusions and

TABLE XIII.

Auvergnose (basalt). From a dike in the northern region of Norrsand, N. Ulfön. (Analyst, N. Sahlbom.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	0,50	—	—
H_2O (above 105°) . .	2,00	—	—
SiO_2	45,85	0,7642	50,40
TiO_2	1,37	0,0171	1,13
Al_2O_3	16,86	0,1653	10,90
Fe_2O_3	2,70	0,0169	—
FeO	11,00	0,1528	12,30
MnO	0,18	0,0025	0,17
CaO	7,37	0,1316	8,68
MgO	7,92	0,1980	13,06
K_2O	0,89	0,0095	0,63
Na_2O	2,44	0,0394	2,60
P_2O_5	0,29	0,0020	0,13
S	0,09	0,0028	—
CO_2	0,05	0,0011	—
BaO	traces	—	—
	99,51		

Quantitative classification

Formula	Mol.	Wt.		Norm				
$K_2O . Al_2O_3 . 6 SiO_2$	95	× 556	= Orthoclase	= 5,282	F	58,287	Sal	58,287
$Na_2O . Al_2O_3 . 6 SiO_2$	394	× 524	= Albite	= 20,646				
$CaO . Al_2O_3 . 2 SiO_2$	1164	× 278	= Anorthite	= 32,359				
$CaO . SiO_2$	85	× 116						
$MgO . SiO_2$	53	× 100	= Diopside	= 1,938				
$FeO . SiO_2$	32	× 132						
$MgO . SiO_2$	826	× 100	= Hypersthene	= 14,860	P + O	31,308		
$FeO . SiO_2$	500	× 132						
$2 MgO . SiO_2$	1101	× 70	= Olivine	= 14,510				
$2 FeO . SiO_2$	667	× 102					Fem	38,784
$FeO . Fe_2O_3$	169	× 232	= Magnetite	= 3,921				
$FeO . TiO_2$	171	× 152	= Ilmenite	= 2,599	M	6,520		
$3 CaO . P_2O_5$	20	× 310	= Apatite	= 0,620	A	0,956		
FeS_2	28	× 120	= Pyrite	= 0,336				
CO_2	—		=	= 0,050				
H_2O	—		=	= 2,500				

Class III	Order 5	Rang 4	Subrang 3
$\frac{Sal}{Fem} = \frac{58,29}{38,78} < \frac{5}{3} > \frac{3}{5}$;	$\frac{Q}{F} = \frac{O}{58,29} < \frac{1}{7}$;	$\frac{K_2O + Na_2O}{Ca\,O} = \frac{489}{1316} < \frac{3}{5} > \frac{1}{7}$;	$\frac{K_2O}{Na_2O} = \frac{95}{391} < \frac{3}{5}$
Salfeman	Gallare	Auvergnase	Auvergnose

Osann's classification

s = 51,66 n = 8,05
A = 3,23 a = 1,72 k = 0,84.
C = 7,67 c = 4,10
F = 26,54 f = 14,18

sacciform penetrations of the groundmass are more evident and have greater development. It is possible that the «inclusions» are not inclusions at all, but sacciform penetrations, or «quasi-inclusions», and that they appear as inclosures as a consequence of the manner in which the section cuts the mineral. A section parallel to the axis of a sacciform penetration will show its true nature, but in a section perpendicular to that axis the same thing will have the appearance of an inclusion. However, there is one circumstance that must be taken into consideration: some of the inclusions in question are more fine-grained than the groundmass and others are the same as the groundmass. IDDINGS, in his work «Igneous Rocks», p. 202, says that «cases occur in which innumerable small crystals of one or more substances first form in a labile, or highly supersaturated, condition of these substances, and are followed by the production of large crystals, phenocrysts, of another substance which form in a metastable condition. An example is furnished by a porphyry in which microscopic crystals of pyroxene and magnetite constitute much of the groundmass and fill phenocrysts of lime-soda-feldspar as inclusions, but those inclosed in the feldspar phenocrysts are not so large as those in the groundmass, showing that the latter continued to grow after the others stopped because of interference by the growing feldspar phenocrysts.»

In my case, groundmass inclusions occur indifferently in the feldspar and in the olivine phenocrysts, although in the groundmass the plagioclases act as an important constituent. Moreover, in some cases I have observed that the groundmass in the innermost part of those «bags» is more fine-grained than elsewhere. This may be a consequence of a higher viscosity in their interior. Hence, the fact that the observed «inclosures» are more fine-grained than the groundmass can not be used as a criterion for deciding if it is a true inclusion or if it is only a quasi-inclusion, with communication with the surrounding groundmass.

The *groundmass* is constituted principally of plagioclase and ferro-magnesian minerals, in addition to magnetite and glass.

I have not been able to determine with certainty the nature of the plagioclases of the groundmass, but they are probably acid labradorites or andesines.

The ferro-magnesian minerals have not been determined as a consequence of their minuteness; together with the glass they fill the interstices between the plagioclase lists.

The whole has the same appearance as the texture which ROSENBUSCH calls «*doleritisch*».

I have not observed apatite, though the analysis of the rock led me to presume its existence.

In the region of the contact between this dike and the diabase the groundmass becomes more and more fine-grained.

The feldspar phenocrysts are perhaps somewhat smaller; the greatest of those in the slice examined is about 2 mm. in length, in the direction

(010) (001); the other dimensions have the same proportion as those of the crystals in the middle of the dike. The olivine phenocrysts are a little smaller, too, and the groundmass inclusions are not so common.

At a distance of about two millimeters from the contact the groundmass is composed of hardly noticeable feldspar microlites, imbedded in a dark glass-mass. This glass becomes more and more brown, and the feldspar microlites disappear. At the contact itself the groundmass is converted into a brown glass, and scattered in it occur the relatively large phenocrysts.

If I should interpret the described phenomena from this rock in accordance with the views prevailing among petrographers, I should then say that the phenocrysts were built during the so-called intratelluric period, and the sacciform penetrations of the groundmass were phenomena of corrosion. I shall not dispute that, in some cases, this interpretation might be right, but I only intend to show that, in my case, the geological and petrographical conditions lead one to seek after some other, more satisfactory explanation.

ZIRKEL was one of the first to express ideas conflicting with the hypothesis of intratelluric crystallisation of the phenocrysts.[1]

WHITMAN CROSS, in a discussion of this question,[2] comes to nearly the same results as ZIRKEL. Alluding to the large orthoclase phenocrysts observed in some laccoliths, he inclines to the opinion that they are to be regarded as wholly developed after the intrusion. «The dikes of the Ruby range», he adds, «cutting late Cretaceous strata, are predominantly porphyritic, but in the larger conduits there is a transition to the purely granular, and in certain masses the only porphyritical constituent is orthoclase, a local development in the final stages of consolidation.»

L. V. PIRSSON has studied the subject[3] in a paper «On the Phenocrysts of Intrusive Igneous Rocks», and considers that, in the case of intrusive igneous rocks of the more acid feldspathic kinds, it has been observed that, while the central parts are porphyritic, the peripherical zones are quite without phenocrysts, and sometimes the border is aphanitic with an allotriomorphic structure; and, if the magma had contained phenocrysts before coming to rest, they would occur in the border zone as well as elsewhere.

He mentions some dikes and sheets from the Judith Mts. of Montana, which are of the same composition, and cut the sedimentary strata at nearly the same levels. These he considers as contemporary. Some are porphyritic, but others not.

He considers no more than one period of consolidation necessary for all intrusive rocks, both granular and porphyritic.

[1] Lehrbuch der Petrographie Zweite gänzlich neu verfasste Auflage. Leipzig 1893. Erster Band. p. 465 and 737.

[2] U. S. Geol. Surv. Fourteenth Annual Report. Part II. 1892—93, p. 231.

[3] American Journal of Science. Ser. 4—7. 157. 1899, p. 271.

Moreover, PIRSSON regards the viscosity of the magma as an important factor in the very siliceous magmas, and points out the significance of mass action in the formation of the recurrent phenocrysts.

W. O. CROSBY, in a publication «On the origin of phenocrysts, and the development of the Porphyritic texture in igneous rocks»,[1] agrees with PIRSSON in the opinion opposing the theory that an abrupt change in the rate of cooling is essential to the formation of the porphyritic texture in intrusive rocks, and also in regarding the viscosity of the magma as a factor of importance; but he remarks that, beyond this, the development of his ideas is along quite different lines.

The conclusions to which he arrives in the publication named are chiefly based on observations in the granite batholith of Blue Hills, south of Boston.

The granite of this batholith, according to CROSBY, passes insensibly upward into granite-porphyry, and then into quartz-porphyry. The quartz-porphyry forms the contact-zone between the granite batholith and the Cambrian strata.

He declares that the phenocrysts of the quartz-porphyry do not necessarily imply an abrupt change in the rate of cooling, and explains the phenomenon of crystallisation as follows: «At the beginning of solidification, when the crystallising magma has, we will say, its maximum liquidity, each growing phenocryst of quartz and feldspar is able to derive material from a considerable volume of magma. But with continued cooling the magma becomes more and more viscous and molecular flow more restricted, until finally the molecular flow is unable to keep pace with the rate of solidification and new centers of crystallisation are established between the phenocrysts and the growth of the phenocrysts is virtually arrested.»

T. A. WATSON suggested to CROSBY «that when during the growth of the phenocrysts, the magma becomes over-cooled and diffusive crystallisation is imminent, it may be precipitated by an earthquake shock, which would give the sudden increase of pressure which the accepted theory requires.»

It seems a curious feature of CROSBY's statement that, according to his experience with prophyritic dikes, the phenocrysts are, as a rule, neither peripheral nor central in the dike, but characterise intermediate zones.

HARKER and CLOUGH,[2] in their description of the porphyritic basalt sills of Soay, mention that the porphyritic feldspars are larger and more abundant in the centre of a sill, and gradually diminish in size and abundance towards the contacts. CLOUGH has noticed this phenomenon very often and concludes that the phenocrysts are developed *in situ*.

[1] The American Geologist. Volume XXV. January to June, 1900, p. 299.

[2] The Tertiary igneous rocks of Skye. Mem. of the Geol. Surv. of the United Kingdom. Glasgow 1904, p. 269.

H. A. MIERS, in his Presidental address to the section of Geology at Johannesburg,[1] applies the results of his experiments on the metastable and labile conditions in supersaturated solutions to explain the growth of porphyritic crystals. «These must have generally originated throughout the liquid as sportaneous nuclei if the magma entered the labile state, or may have been started by inoculation or cooling at the margin, if the magma as a whole remained in the metastable state.

In the latter case suppose that, further, somewhat sudden cooling brings the magma to the labile condition, then there will be a sudden and spontaneous second growth of nuclei, which will not be able to attain the dimensions of the porphyritic crystals; we have here all the conditions necessary for a second generation of one of the constituents of the rock».

VOGT studies the problem in two of his remarkable publications:[2] Physikalish-chemische Gesetze der Krystallisationsfolge in Eruptivgesteinen. He embraces ROSENBUSCH's ideas, except in respect to the intratelluric crystallisation of the phenocrysts. In this connection he says: die Ausscheidung der Einsprenglinge hat in überaus zahlreichen Fällen in situ stattgefunden (oder in demselben Niveau wie diejenige der Grundmasse oder der Glasbasis).

IDDINGS[3] believes that sudden loss of gases and sudden changes in temperature can cause a sudden change in the rate of crystallisation and in this way originate a hiatal porphyritic fabric. He is of opinion that a porphyritic fabric may be produced by the growth of crystals of those substances which are present in greater amount in the solution.

In agreement with MIERS he opines that one substance may separate in comparatively large crystals in a metastable condition, while others remain in solution until they reach a labile condition, when they separate suddenly at innumerable points as comparatively small crystals, forming a groundmass. But he does not explain how the crystallisation can be initiated in the metastable state.

HARKER's opinion, given in his latest valuable work,[4] is that in the volcanic rocks the phenocrysts are of intratelluric origin, but in hypabyssal rocks their development has in general occurred *in situ*. He applies the eutectic theory, and believes with BECKER[5] that the groundmass tends to the eutectic composition and that the phenocrysts often represent the excess over the eutectic proportions.

I have referred briefly to the views of geologists which do not altogether agree with, or are absolutely opposed to, the ideas of ROSENBUSH,

[1] Report of the British association for the Advancement of Science. 1905, p. 375.

[2] TSCHERMAK's Mineralogische und Petrographische Mitteilungen. Bd XXIV. 1905, p. 453 and Bd XXVII. 1908, p. 169.

[3] Igneous Rocks. Vol. I. 1909, p. 201.

[4] The natural history of igneous rocks. London 1909, p. 262.

[5] U. S. G. S. Twenty-First Annual Report 1899—1909. Part III, p. 519.

which, I believe, are those most generally accepted among petrographers; and now I shall set forth my own opinion, based chiefly upon studies of basalt and doleritic dikes which cross the Ulfö-diabase, and, further, of the contacts of this diabase with the older granite.

The metastable Zone. — In the above description of the basalt dike from the northern region of Norrsand, I said that at a distance of about two millimeters from the contact the groundmass is composed of hardly noticeable feldspar-microlites imbedded in a dark glass-mass. This glass becomes more and more brown, and the feldspar microlites disappear. At the contact itself the groundmass is converted into a brown glass, and, distributed in it, occur the relatively large phenocrysts. There is, however, one phenomenon which, as far as I know, has not been noticed before. In a zone of about 3 or 4 mm. in breadth, measured from the contact, there is an accumulation of relatively large phenocrysts, but outside this region the phenocrysts are much smaller and less mumerous. I cannot follow the textural variations of the rock the whole way to the central part. But in the central region the phenocrysts are somewhat bigger than in the contact zone.

On the other hand, the groundmass becomes more and more crystallinic and the granularity increases towards the central region.

Consequently, if we trace curves with the distances from the contact towards the centre as abscissæ and the granularity represented by the ordinates, we have that, for the phenocrysts, the curve has one relative maximum at the contact, the absolute maximum being in the central region. The minimum is somewhere near the contact zone. All this taking into consideration only one half of the dike — from the contact to the centre.

For the groundmass the curve has a minimum at the contact and a maximum at the central region of the dike.

In a promontory in the southern region of Norrsand there are several basalt and diabase dikes; one of them, of about 6 m. in breadth, is an olivine-diabase or dolerite. A dislocation of two meters cuts the dike at some meters from the shore.

It consists of *plagioclase, augite, olivine, magnetite* and *mica.*

In the central parts of the dike the rock is porphyritic with *plagioclase* and *olivine phenocrysts.* The plagioclase phenocrysts are zonally built and, as a rule, they show a recurrence in the composition of the zones.

Their composition is as follows.

Section parallel to (010). Crystal with a length = 1,7 mm. and breadth = 1,1 mm.					
(central part)	I	II	III	IV	V (outermost shell)
Ext'n angle	— 33,8	— 21,5	— 26,3	— 5,7	0,0
	$Ab_{10}An_{90}$	$Ab_{42}An_{58}$	$Ab_{33}An_{67}$	$Ab_{62}An_{38}$	$Ab_{68}An_{32}$

Between I and II, II and III, III and IV there are other, very thin zones, alternately basic and acid.

The *groundmass* is composed of plagioclase and of the other minerals named.

The *plagioclases* are zonally built, and the shells have a composition between $Ab_{26}\ An_{74}$ and $Ab_{68}\ An_{32}$. The dimensions are generally less than 0,5 mm.

The crystals in this case, as well as the phenocrysts, are tabular parallel to (010).

The zones in the plagioclases are well limited, excepting the more acid outermost shells, which are usually somewhat irregular.

After the plagioclases, the *augite* is the most common mineral.

The colour is reddish-violet with a tinge of brown.

Pleochroism is not observable when the transmitted light is observed along the directions of the axes of the ellipsoid (X, Y and Z), but in other directions pleochroism is noticeable.

It seems as if the directions of the minimum of absorption approach the plane of the optic axes and are somewhat oblique to them, and that of the maximum of absorption corresponds with the direction of the optic normal, which is approximately the same as that in the direction of the bisectrices.

Then we have approximately:

$$Y = X = Z = \text{reddish-violet.}$$

For the axis A the dispersion is very noticeable, but not for the axis A'.

This augite corresponds to the basaltic augite of ROSENBUSCH.

It is generally very fresh, and occurs in crystals relatively large, which act as a matrix for the plagioclases. The mean of some measurements of the magnitude of the sections is $(2{,}40 \times 1{,}10)$ mm^2. The augite has very irregular outlines and has been the last mineral to crystallise. From the qualitative point of view, this rock is like the diabase of the quarry to the west of Hamnberget, but in the former the quantity of augite is greater than in the quarry diabase, for which reason the ophitic texture appears in this case.

The *olivine* comes after the augite in quantity, generally occurring in rounded crystals. The colour is white, very often with a pale yellowish tint. It is altered, but there are a great many fresh crystals.

The alteration-products are serpentine and bowlingite, and the process of alteration has taken place in the usual way.

There are porphyritic crystals of about 1 mm. in diameter, but they are generally smaller — less than 0,5 mm.

The *titaniferous magnetite* comes after the olivine in quantity, and as a consequence of its relatively large quantity, this mineral may be considered as one of the essential minerals. The crystals generally show a section of less than 0,30 mm^2.

Biotite is observed in small quantities, sometimes deposited round the magnetite crystals.

Apatite occurs in very small needles.

The phenocrysts, both olivine and plagioclase, initiate the solidification; but, judging from the appearance of the final stage of the crystallisation, their growth was interfered with by the formation of the groundmass-minerals.

It is evident that the plagioclase phenocrysts were the first to begin the separation process. They sometimes enclose small plagioclase and olivine crystals, but these generally occur in the border-zone.

When the crystallisation of the plagioclases was somewhat advanced the olivine began to set free some crystals, but in less amount than the preceding mineral; then, after some time, the number of crystallisation-centra grew larger and larger.

This process seems to have taken place gradually, without discontinuity, because there are crystals of many magnitudes between the phenocrysts and the groundmass crystals, and we see that, at the same time, the crystals become smaller and their number becomes greater.

During the interval of time in which the separation of the crystals of the groundmass took place the phenocrysts continued to grow. This is shown partly by the fact that the chemical composition of the outer shells of the phenocrysts corresponds with that of the plagioclases which form the groundmass, and partly by the evident interference in the growth of the outer zones of the phenocrysts, caused by the crystals of the groundmass. Moreover, in their outer regions, the plagioclase phenocrysts enclose plagioclase and olivine crystals, and the same is the case with the olivine phenocrysts.

Before the end of the process of the crystallisation of the minerals named the magnetite began to separate; last of all solidified the augite.

The biotite crystallised after the magnetite; and it is curious that the former mineral, in the rocks of this composition from this district, even when in small amounts, separates immediately after the magnetite and surrounds it.

The rock is holocrystalline.

The plagioclase phenocrysts have sections of between 1 and 2 mm.^{2}, while the olivine phenocrysts show sections of about 1 mm^2.

The sections of the plagioclases of the groundmass are generally less than 0,25 mm^2, and the dimensions of the olivine crystals are also below that figure.

The magnetite is also less than 0,25 mm.^{2} in sectional area and the augite occurs in crystals of between 2 and 3 mm.^{2} in sectional area.

The mass of the rock is consequently decimillimeter-grained.

The fabric is between seriate porphyritic and seriate porphyroid.

$$\frac{\text{g. m.}}{\text{ph.}} > \frac{7}{1} = \text{Perpatic.}$$

The rock is mediophyric.

The groundmass very often shows a beautiful ophitic fabric. The proportions between the components of the rock are such that the augite separates last, in relatively large crystals; and the plagioclases of the groundmass, being small in comparison with the augite crystals, have a relatively great euhedrality. These are necessary conditions for the development of the ophitic fabric.

The preceding description refers to the middle of the dike — thus 3 meters from the contact.

At the contact the rock is vitreous and there are numerous plagioclase and olivine phenocrysts distributed in a groundmass of glass. The plagioclase phenocrysts are of the same composition as those at the centre of the dike, and they are likewise zonally built, but not so big. They measure about 0,80 mm. in length, sometimes 1,00 mm., and in one case 1,50 mm. For comparison we will recall the fact that the largest porphyritic plagioclase in the middle of the dike measured 2,30 mm. in length.

Albite and Carlsbad twinning are the most common; in one case I observed baveno twinning.

Inclusions and «bags» of glass have often been observed in the plagioclases. Sometimes the crystals are irregular, but in the majority of cases they have subhedral outlines. Alteration-products are rare, the feldspars in most cases being quite fresh.

The olivine phenocrysts, on the contrary, are often decomposed and are generally elongated in a direction parallel to c, and in some cases they attain 1,5 mm. in the same direction.

The olivine, in a yet higher degree than the plagioclases, encloses the groundmass, and its outlines become irregular as a consequence of the «bags», or sacciform inclusions, in communication with the groundmass. This holds true especially for big crystals. The small crystals are generally more regular.

The order of crystallisation at the contact has been similar to that in the middle of the dike. The separation of the plagioclases began at some centres of crystallisation lying at about 1,00 mm. from each other. After some time the olivine began its crystallisation, and afterwards the separation of new generations of crystals took place around more numerous points of crystallisation. Finally the remainder congealed as glass. The relation between glass and crystals is:

$$\frac{\text{crystals}}{\text{glass}} < \frac{5}{3} > \frac{3}{5}.$$

The fabric is seriate porphyritic.

The glass is perhaps present in somewhat greater quantity than the crystals. Thus the rock is hyalocrystalline. In a direction from the contact to the inner region of the dike the glass becomes more and more

crowded with microlites, and at about 2 centimeters from the inner region there is no glass at all, and the magnetite and augite are then discernible. Thus, the ground-mass increases in crystallinity in the usual way, from the contact to the central regions.

The phenocrysts do not follow that rule. There is a zone of about 1 cm. in breadth, inward from the contact, where the porphyritic crystals — olivines as well as plagioclases — occur, as has been explained before; but outside this region the phenocrysts are much smaller and less numerous.

This is quite the same phenomenon as occurs in the basalt in the northern region of Norrsand, but here it is much more pronounced.

At 25 mm. from the contact the average size of the groundmass crystals is about (0,08×0,01) mm.^{2}, and the largest phenocrysts (0,53×0,08) mm.^{2} Consequently, the dimensions are about those of the biggest plagioclases from the contact zone.

At 50 mm. from the contact the plagioclases of the groundmass have an average length of 0,18 mm. and the phenocrysts of about 0,50 mm. Their respective areas are 0,005 mm.^{2} and 0,050 mm.^{2} The latter are very scattered, and the distance between them may exceed 6 mm. In reality there is no sharp and striking contrast in size between the groundmass crystals and the largest phenocrysts. The fabric is what IDDINGS calls seriate phorphyroid. Consequently, we find that the relations between the areas of the porphyritic crystals and those of the groundmass are: At the contact $\frac{3755}{0}$; 25 mm. from the contact $\frac{53}{1}$; 50 mm. from the contact $\frac{10}{1}$, and at the centre of the dike (3 m. from the contact) $\frac{8}{1}$.

At Vattenviken there are some other dikes which show the same phenomena as the foregoing. One of them, of about 1 m. in breadth, is divided into two by an albititic rock, forming a double dike.

The composition of this basaltic or diabasic dike is the same as that in the preceding case. The only difference is that this rock is finer-grained and perhaps not so fresh. Here and there the augite is somewhat altered. The order of separation of the minerals is quite similar, and here also the plagioclase is the mineral that predominates in the rock.

The plagioclase phenocrysts occur with sections of about (1,05×0,27) mm.^{2}, zonally built, and the composition of the zones varies between Ab_{16} An_{84} and Ab_{50} An_{50}.

The plagioclases of the groundmass also show zonal structure. The mean dimensions of their sections are (0,30×0,05) mm.^{2}; on (010), (0,30×0,15) mm.^{2} The composition is between Ab_{40} An_{60} and Ab_{56} An_{44}. The plagioclases are unaltered, and have subhedral and anhedral outlines. Even among those of the groundmass the *subhedrality* may be very well marked. The olivine phenocrysts show sections of about (1,05×0,60) mm.^{2}

They are subhedral and anhedral and very often show plagioclase inclosures in the peripherical regions of the crystals.

The other minerals, augite and magnetite, occur in the same manner as in the above-described case; texture and crystallinity are also about the same. At about 4 cm. from the contact the rock is quite crystalline. Generally it is observed that the phenocrysts occur in clusters of fifteen or even twenty crystals; sometimes less. This is probably a phenomenon that came about during the last period of their crystallisation, but before the groundmass began to separate.

The sections of some of the porphyritic crystals here are as large as in the centre of the dike, but on the average they are somewhat smaller, and the same is the case with the crystals of the groundmass.

At 2 cm. from the contact the sections of the groundmass plagioclases are about $(0{,}22 \times 0{,}03)$ mm.^{2}, and there is some glass.

There is a plagioclase phenocryst with an area af $(2{,}25 \times 0{,}38)$ mm.^{2}, which is the largest observed in the rock. In its periphery there are numerous inclosures of the groundmass and for this reason its outlines, when considered in detail, are very irregular. Some determinations of the extinction angle in sections parallel to (010) gave the same results as for the phenocrysts in the centre of the dike.

Finally, nearer the contact, is observed the same phenomenon as in the above-described dikes. In a zone of about 5 mm. in breadth at the contact are imbedded in a glassy groundmass relatively large phenocrysts, clustered along the contact line. Outside this zone there is a region of about 5 mm. in breadth, where the phenocrysts are relatively rare and smaller; then they become bigger towards the centre of the dike, but occur in clusters.

Beautiful fluidal phenomena are observed around the porphyritic crystals and along the contact wall. There is an evident tendency in the crystals — phenocrysts as well as groundmass crystals — to take a direction parallel to the contact surface.

Consequently, there is a well-defined zone along the contact where the phenocrysts are packed together; they are, besides, larger and more numerous than in the neighbouring region.

It looks as if this phenomenon is common in the region, because I have observed the same thing not only in other dikes in Nordingrå, but also in the contacts between the big bodies of Post-Jotnian diabase and the Sub-Jotnian rocks.

At Långviken, in S. Ulfön, the contact between the diabase and the granite is interesting for several reasons. Here I shall only point out that the above-described contact peculiarity is also observed there, but more developed. The contact zone is about 8 mm. in breadth and the limit inward very sharp.

At Svartbergsviken, on the east coast of the northern island, occurs the same thing, but it is not so evident as at Långviken. It seems to me

that this phenomenon can be explained in the light of some laboratory experiments.

It is known that by cooling a liquid very slowly it is possible to reach a lower temperature than that of the fusion point, but it was thought that to get a liquid overfused repose was a necessary condition. In a paper «Sulla soprafusione dell'acqua e delle soluzioni saline in movimento»,[1] V. MONTI gives an account of his experiments. He first used common water, moving it with an ordinary agitator, whose movements up and down were about 80 a minute. The water remained in the liquid form to — 0,8°. Then he used a helix, rotated by means of an electric motor, with a velocity of between 350 and 500 revolutions per minute, and in this way he was able to retain the water in the liquid state to — 3°,6 C. At the same time as the water was agitated by the helix he hammered upon the table on which the apparatus was; moreover, he made sudden changes in the helix's velocity of rotation and introduced a glass rod, but nothing caused the crystallisation of the water. But with the introduction of a piece of ice he caused the water to freeze.

With an improved apparatus, and using boiled and distilled water, he could keep the water in the liquid state at a temperature of — 7°,77. The agitator in this experiment had a rotation velocity of 500 revolutions per min. and the water-reservoir 100 revolutions in the contrary sense.

He made analogous experiments with saline solutions.

Ostwald[2] designates by metastable the region of overfusion which inmediately follows the point of fusion, where the presence of the solid phase is necessary to bring about solidification, and designates by labile the condition in which crystallisation takes place spontaneously.

C. L. DE COPPET,[3] in a work «Recherches sur la surfusion et la sursaturation», shows how the *salol* with a fusion point of + 42°,6 remains overfused at ordinary temperatures for several years.

The *salol,* having been overfused for more than a month, never crystallised as a consequence of agitation at temperatures between + 7° and + 12°. Some of the liquids experimented on have, however, crystallised a long time afterwards, at temperatures of between 12° and 25°.

The influence of agitation was zero, even for supersaturated solutions of sodium-bromure.

The agitation caused the crystallisation of the heptahydrate of sodium-sulphate in some solutions — supersaturated as regards this salt — which were in the labile state. But it was without effect at higher temperatures, at which, however, had been observed spontaneous crystallisation of the heptahydrate in the same solutions at rest.

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[1] Atti della R. Accademia delle Scienze di Torino. Volume Vigesimosettimo 1891—92. Torino 1892. — p. 94.

[2] Zeitschr. phys. Chem. vol. 22. 1897, p. 302, and his text-books in Chemistry.

[3] Annales de Chemie et de Physique. 8me Série. Tome X 1907. Paris. — p. 457.

COPPET, as a consequence of his observations, believes that there is not a sharp and fixed limit between the labile and the metastable states, and that the copious separation of crystals, which MIERS considers as indicating the limit named, takes place when the solution is already in the labile state.

MIERS, ISAAC and CHEVALIER, in a series of interesting papers, have thrown much light on these questions of such great importance.[1]

MIERS and CHEVALIER, in the paper «On the crystallisation of sodium nitrate» published in «The Mineralogical Magazine» come to the result that «An aqueous solution, either by cooling without serious change of concentration, or by evaporation of the solvent without serious change of temperature or by both, becomes supersaturated and passes first into the metastable state (in which it will only crystallize by inoculation with a crystal of the solute or of an isomorphous substance) and then quite suddenly into the labile state (in which it may crystallise spontaneously). Spontaneous crystallisation in the latter is generally induced by shaking or by friction, but in any case it is started by introduction of a crystal of the solute or of an isomorphous substance; whereas the introduction of such a crystal into the metastable solution only produces a few crystals in its immediate neighbourhood».

CHEVALIER, in his publication «On the crystallisation of potash-alun» (the same Journal, p. 134), concludes that a supersaturated drop of potash-alun, which is either cooling or evaporating, or both, passes successively into two different states: one in which no cubic crystals appear unless introduced; but an introduced crystal grows and reproduces itself, either in its immediate neighbourhood, or when stirred through all parts of the drop. This is the metastable state. The second state is one in which birefringent sphero-crystals may, and do, form spontaneously, or an introduced particle of octahedral alun sets up at once, throughout the whole drop, a very perfect microcrystalline structure. Even for binary and ternary mixtures MIERS and Miss ISAAC have studied the principles of crystallisation, coming (in respect to the features of the labile and metastable states) to results analogous to those given above. They have experimented with a mixture of *salol* and *betol;* and with mixtures of solutions of sodium nitrate and lead nitrate.

I shall, in the following lines, try an application of the foregoing laboratory results to the phenomena described above from the contacts between the dikes and the diabase on the east coast of northern Ulfön, and between the diabase and the granite from both islands.

[1] MIERS: Report of the British association for the advancement of science. S. Africa 1905. p. 375. — MIERS and ISAAC: Journal of the Chemical Society. Vol. 89. 1906. Transactions 1. London. p. 413. — MIERS and CHEVALIER: The Mineralog. Magazine. 14. 1904—1907. London. p. 123. — MIERS and Miss ISAAC: Proceedings. Royal Society. Ser. A. 79. 1907. p. 322. — Miss ISAAC: Journal of the Chemical Society. Vol. 93 1908. Transactions 1. London. p. 384.

Let us imagine one of those dikes when the magma was liquid, completely filling the space between the diabasic walls.

That magma may be considerated as a solution, principally of the minerals *plagioclase, olivine, augite, titaniferous magnetite* and *biotite*.

The composition of the country-rock was of the same minerals.

Then, if we suppose the magma to be cooling, it will after some time become supersaturated. In the first state, the metastable, nothing except inoculation could bring the magma, or a part of it, to crystallise. IDDINGS[1] asks to what extent an earthquake shock will disturb the equilibrium in a metastable intruded rock magma. All the laboratory experiments show that a solution in the metastable state is not disturbed at all by mechanical means, and for that reason I believe that an earthquake shock will have no influence on the crystallisation of a metastable magma. On the contrary, when the magma has passed into the labile condition an earthquake shock may induce crystallisation. In the case under consideration it is quite evident that our magma began to solidify at the metastable state, as a consequence of inoculation with the minerals of the country-rock, which, as I stated above, are identical with those in solution in the dike magma.

The inoculation took place along the whole wall, and had the same effect as if we had stirred the magma at the contact — in this case with a crystal of plagioclase. Crystallisation centra were then generated, but at some distance around the inoculating crystals.

The magma continued to cool and the crystals in the metastable zone continued to grow, it may be, surrounded by a halo of labile solution[2]; afterwards, in the central regions of the dike, the magma becomes labile and spontaneously begins to crystallise. The plagioclases separated first — there as well as in the metastable zone — because they predominated in the solution, and consequently the magma was saturated with them first. After the plagioclases had been crystallising for some time the olivine began to separate in both regions, and probably not simultaneously.

The contact magma in the last period of its solidification passed into the labile state because there were some generations of small crystals. These may be those showers of crystals which characterise the beginning of that condition.

Afterwards the liquid remainder of the magma in the metastable zone became glass, and that in the central regions completed its crystallisation.

It seems that VOGT will not assent to such an application of the inoculation theory to rock magmas; his opinion is expressed as follows:[3]

[1] Igneous Rocks. Volume I. — New York. — 1909, p. 160.

[2] MIERS and CHEVALIER: The Mineralogical Magazine. 1906. Vol. XIV p. 123.

[3] Physikalisch-chemische Gesetze der Krystallisationsfolge in Eruptivgesteinen. Tschermak Min. und Petr. Mitteil. Bd XXIV 1905 p. 448. —

»Die bisherigen Versuche hauptsächlich von OSTWALD und seinen Schülern bezüglich der Aufhebung der Übersättigung durch Zusatz von Keim- oder Impfungskörpern sind bei ziemlich leichtflüssigen Lösungen ausgeführt, die Resultate dieser Impfungsversuche dürfen nicht ohne weiteres auf Silikatschmelzen mit überaus hoher Viscosität übertragen werden».

Since 1905 many experiments have been made in inoculation, the results of which may have led VOGT to change his views on these questions. It is necessary to remember that the magmas in question have a SiO_2 proportion of about 45 %; they are consequently rather basic.

On p. 450 of the above-mentioned work VOGT says: »Die von H. A. MIERS (Herbst 1905) betonte Bedeutung zwischen «The Metastable and Labile Conditions» zur Erklärung petrographischer Erscheinungen kann ich nicht zugeben, indem die sogenannte «metastabile Grenze» aller Wahrscheinlichkeit nach bei sehr langer Abkühlungszeit hinfällig wird.»

It may be that this hypothesis has not so wide an application as MIERS believes, but my experience has convinced me that, at least for basic magmas solidifying as dikes and at relatively slight depths, it probably holds good.

That the limit between the metastable and the labile conditions, generally or in some cases, is not sharp does not emply that these states of the solution have no signification for the crystallisation of magmas. The slowness in the cooling of a magma may, perhaps, have a propitious influence on the development of crystals by inoculation, because the magma remains for a long period of time in the metastable state. In respect to the »metastable zone» in the contacts between the diabase and the granite at Långviken, Svartbergsviken etc., I may say that the only mineral from the granite which could promote crystallisation in the metastable condition was the albite.

Further, it may be objected that the olivine separated in bigger crystals in that zone, in view of the fact that the magma was not inoculated with olivine.

This objection could be answered by supposing that the proportions between the olivine and plagioclases were such that, when the magma just becomes saturated with plagioclase and by means of inoculation this mineral began to crystallise, the magma was already supersaturated with olivine. The crystallisation of the feldspars by inoculation could, consequently, in some way make the magma locally labile in respect to olivine.

I am convinced, however, that the magma in the contact region was metastable, and that the crystallisation of the olivine was a consequence of that of the plagioclase. What I mean is that the inoculation with albite was sufficient for the separation of the plagioclase phenocrysts first, and that of the olivine afterwards. MICHAELA VUČNICK [1] found that a fused mixture of hedenbergite and anorthite in the proportions 3 : 1 gave,

[1] Ueber das Verhalten von Silicaten im Schmelzflusse. Centr. f. Min. etc. 1904 p. 295.

after consolidation, a light green, vitrious groundmass. As separation-products occur hedenbergite, augite and anorthite, which are not in all parts uniformly separated. Augite was the first mineral to solidify.

This experiment was performed once more, but the fused mixture was inoculating with anorthite. The result was glass, in inconsiderable amount, angite, anorthite and magnetite.

The augite had separated in rather large quantities and in beautiful crystals; the anorthite occurred but in small quantities and in fine needles, scattered in the groundmass; the magnetite had crystallised in rather large quantities.

The order of crystallisation was: *magnetite, augite, anorthite, augite.*

On fusing hedenbergite and anorthite in the proportions 1:3 and inoculating with anorthite it was observed that the anorthite crystallised in large and beautiful crystals, and the order of crystallisation was generally *magnetite, augite, plagioclase* and, lastly, the *glass;* «aber an einzelnen Stellen scheint der Anorthit sich zuerst gebildet zu haben, eventuell sogar vor dem Magnetit, da er an den betreffenden Stellen diesen nicht als Einschluss enthält, während den Anorthitkrystallen Magnetite anliegen. Es sind dies Stellen in der Nähe der Impfanorthite.»

»Bei diesem Versuche kann man auch ganz deutlich sehen, dass sich der Magnetit durch den Einfluss des Impfens gebildet hat, da er sich ganz regelmässig um das noch vorhandene Impfmaterial angesammelt hat und dieses gewissermaassen umsäumt. Bei diesem Versuche lässt sich also keine bestimmte Reihenfolge für die Ausscheidung geben, diese wäre nämlich im Allgemeinen Magnetit, Hedenbergit, Anorthit, sie ist aber durch den Einfluss des Impfens geändert, und an einzelnen Stellen bildete sich *Anorthit zuerst.*»

In a fused mixture of eleolite and corund in the proportions 9 : 1 Berta Vukits[1] found that inoculation with eleolite not only favoured the crystallisation of eleolite, but also that of corund and of the newly formed minerals sillimanite and spinel. In a mixture of the same minerals in the proportions 5 eleolite: 1 corund, inoculated with coarse corund powder, the corund separated in big and beautiful crystals. The inoculation resulted in less numerous crystallisation centra and favoured the growth of large crystals.

An experiment with augite and olivine in the proportions 9:1 without inoculation gave crystals of olivine, augite and magnetite, in a vitreous groundmass. The augite is not euhedral and occurs as a kind of groundmass in relation to the better-built olivine crystals.

Another experiment with the same minerals in the same proportions, but with the fused mixture inoculated with augite, gave as result that the greater part of the solidified mass was augite. The olivine occurred in very sparse, but typically built crystals. Magnetite occurs as a newly-built mineral.

[1] Beobachtungen an Silicaten im Schmelzfluss. — Centralbl. f. Min. etc. — 1904. p. 705.

The inoculation had a very great influence here. *Olivine was very sparse but was the first mineral separated, though the fused mixture was inoculated with augite.* The augite crystallised in greatest amount and in beautiful crystals. All the laboratory experiments give analogous results in respect to inoculation — in water solutions as well as in fused mixtures of silicates. Then it is not precipitate to apply them to the crystallisation of rock magmas, especially when the observed phenomena are so evidently analogous to those observed in fused silicates and in water solutions.

Consequently, it is very probable that the zone of large crystals (the metastable zone) which I observed in the contact region of basic basalt and diabase-dikes, and even in greater bodies of rocks of the same composition from Ulfön, is caused by a crystallisation induced during the metastable state by inoculation. In the case of the dikes the country-rock is composed of the same minerals as the dike-rock. In the case of the greater diabase body the country-rock could induce crystallisation only with a mineral isomorphous to one of the components of the fused magma. This was albite, which induced crystallisation of basic plagioclases and olivines in the metastable condition.

I say »*it is probable*» because of the complicated nature of those phenomena, and because I am aware that my interpretation might possibly be wrong; but I am persuaded that it must be right.

This phenomenon is presumably best marked in the most basic magmas, and I have never observed it in quartz-bearing rocks.

The width of the »metastable zone» depends, within certain limits, upon the breadth of the intrusion, all the other circumstances being determined and constant.

Uralite-diabases of Sandviken and Norrtaskberget.

Immediately to the south-east of Sandviken (N. Ulfön) there are three diabasic dikes cutting the granite, and one of them crosses the diabase (of the main body). This is seen from a very great distance, when one is coming from the north.

The dikes have weathered away, so that there is a gaping hole called »gethelvetet» (goats' hell) by the fishermen, I presume because their goats fall into the open gap and break their legs, or at best have great difficulty in getting out again.

The dikes are younger than the diabase of the main body and very altered.

The mineral composition is as follows: *plagioclase, uralite, augite, magnetite.* I have not observed olivine, but it is possible that it is weathered away.

The *feldspars* are basic plagioclases, very decomposed. It is generally difficult to determine them. In a section parallel to (010) I found an extinction of $28°{,}5$, which thus corresponded to that of a basic labradorite, $Ab_{27}\ An_{73}$; but they are zonally built, and it is very possible that in the central parts,

of the crystals they are acid bytownites, and in the outer zones acid labradorites or andesines. I do not know their dimensions with any exactitude, because the limits of the different crystals are ill-defined, as a consequence of the accumulation of secondary minerals. In the central region of the dike the dimensions may be $(1{,}0 \times 0{,}5)$ mm^2.

The *augite* is almost completely transformed into uralite. Here and there occur some crystals showing part of the primary minerals preserved. For this reason it is possible to observe all the transitions in the alteration.

The augite is the ordinary reddish-violet variety occurring in the Ulfö-diabase.

The *magnetite* occurs in relatively large proportions, but it is probable that a great deal of it is of secondary origin. It occurs, in part, as irregular crystals of about 0,30 mm. in diameter, in part as rods, and finally as very small grains in the secondary hornblende.

A quite analogous dike is observed at the foot of Norrtaskberget (N. Ulfön) in the neighbourhood of a quarry. The rock is very altered. The feldspars are the same as in the above-described rock, and the augite is completely transformed into uralite. The same richness in magnetite is observed. The crystallinity, granularity and fabric are also the same. It seems that the augite has existed in relatively great amount, so that a tendency to the ophitic texture is observed.

Diabase dike in the region north of Norrsand.

To the north of Norrsand, on the same parallel as Norrbyn, there is a dike cutting the diabase at an angle of about 30° to the horizontal plane. This dike is very noticeable from the sea because of its colour, which, as a consequence of weathering, is somewhat lighter than that of the diabase. The rock is composed of: *plagioclase, hornblende, augite, biotite, olivine, titaniferous magnetite* and *pyrite*. I have not observed apatite.

The *plagioclases* are zonally built, and their zones vary between a basic labradorite, $Ab_{27}\ An_{73}$, and a basic andesine, $Ab_{58}\ An_{42}$. But there may also be basic kernels of the composition of an acid bytownite. They are tabular according to (010) and well preserved. The commonest twinning is that of the albite type, but often is observed twinning according to the Carlsbad and, more seldom, the pericline laws.

The plagioclases show a high euhedrality when imbedded in the large augite crystals, and there the ophitic texture is sometimes well developed.

The mean dimensions of the plagioclases are about $(1{,}00 \times 0{,}30)$ mm.^{2}

In the contacts with the olivines the plagioclases do not show quite independent outlines; this need not be interpreted as meaning that the olivine crystallised first, but it may be that the olivine separated before the outer zones of the plagioclases.

The *augite* is the same as that of the diabase of the massive, but it

has been very much altered to hornblende. The augite is quite anhedral. It has been the last mineral to separate, filling the spaces between the other minerals. The alteration of the augite into uralite has taken place in the ordinary way, from the peripherical regions towards the inner part of the crystal. The first step in the alteration is that each crystal of the augite becomes a crystal of hornblende, then this hornblende is transformed into a fibrous accumulation.

Sometimes are observed small regions of hornblende in the central parts. This has probably been an alteration along a cleavage plane.

The substitution is parallel.

For the hornblende we have the following absorption formula: Z = brownish-green > Y = brownish-green > X = pale brownish-green. In some parts the hornblende becomes paler and paler, and finally it is transformed into a substance of very low birefringence — a kind of chlorite.

The *biotite* has an absorption formula: Z = dark red-brown > Y = dark red-brown > X = pale yellow. It generally occurs surrounding the magnetite. This mineral is also altered. The first stage is a change of colour, from brown to green; then it becomes paler and the birefringence decreases, the mineral going over to chlorite.

The *olivine* generally occurs in irregular and rounded crystals, but it seems to be one of the minerals which separated first. Its colour is yellowish white, and it is altered into serpentine and bowlingite. The olivine crystals are, in the mean, 0,40 mm. in diameter.

The *titaniferous magnetite* is observed in anhedral and subhedral crystals; it has crystallised after the olivine and plagioclases, but before the augite. The sectional dimensions are about $(0{,}40 \times 0{,}20)$ mm.^{2}, but there are crystals as big as $(1{,}00 \times 0{,}20)$ mm.^{2} and $(0{,}70 \times 0{,}40)$ mm.^{2} in section. Sometimes it is surrounded by biotite, and, in some cases, altered to leucoxene. There is secondary magnetite from the decomposition of the olivines.

The *pyrite* occurs in very small quantities in irregular crystals.

The order of crystallisation in this rock has consequently been: first *plagioclases* and *olivine*. Which of these minerals was the first I cannot say with certainty. The olivine occurs as inclusions at least in the peripherical regions of the feldspar crystals, but I have never observed a feldspar included in an olivine crystal. I believe, for this reason, that the olivine separated first, and after it solidified the plagioclases. Then the magnetite crystallised, and last of all the augite.

Uralite-diabase of Blåberget.

On the south-west coast of N. Ulfön, at about 700 m. from the western entrance of Ulfösundet, to the north, there is a dike of nearly 12 m. in width at the sea-shore. The dike cuts the granite in a direction S. 65 E, and it is visible at a distance of 250 m. from the shore.

The rock of the dike is green with shades of red and fine-grained, and its constituent minerals are: *feldspars, uralite, quartz* and *magnetite*.

The *feldspars* are very altered; so much so that their determination is impossible. Here and there one can see twinning, and from this we can assume that the lath-shaped feldspars are plagioclases. Their mean sectional dimensions are $(0{,}70 \times 0{,}20)$ mm.^{2}.

The *uralite* occurs in more irregular crystals, but they are somewhat flattened also, and have nearly the same dimensions as the plagioclases.

In the intervals between the minerals named occur orthoclase and quartz in graphic implication.

The plagioclase and uralite are in nearly the same proportions.

The *magnetite* occurs as an important constituent of the rock, in irregular crystals half as big as the plagioclase and uralite crystals.

A rough determination of the mineral proportions give 35 % uralite, 30 % plagioclase, 20 % quartz and orthoclase, and 15 % magnetite; but these figures are only intended to give an idea of the rock, and not as a basis for calculations.

The implication of quartz and orthoclase has very little importance for the texture of the rock, and it has an apparently equigranular fabric. Nearer the contacts the rock becomes greener, and it looks as if the uralite occurs in greater quantity there and in elongated crystals.

Quite near the northern contact of the dike there occurs a fragment of granite as an inclusion in the dike-rock. The fragment has rounded outlines, and its length is 45 cm. and its greatest breadth 30 cm. From the narrowest part of the fragment a very fine vein of granite goes into the dike-rock. It has a length of about 15 cm. and a breadth of 1 mm.

Around this inclusion, and especially on the sea side, there are smaller fragments, sometimes irregular in form, but more often rounded, with the appearance of crystals. The rounded inclusions have, in general, an even, rounded outline, but in some cases «bags» of the dike-rock magma penetrate it. These rounded inclusions give to the rock a porphyritic appearance. Their dimensions vary; the largest may be of about 2 cm. in diameter, but they are sometimes very small, only 2 or 3 mm. in diameter. See Plate X, Fig. 2.

The dike-rock round these inclusions is somewhat different from that described from the central region. The uralite increases in quantity, and it occurs in branching aggregations, while the proportions of orthoclase and quartz have also increased.

The rounded inclusions are composed of a mixture of albite and orthoclase. In them are included magnetite and quartz, which last mineral occurs in irregular crystals and never in graphic implication.

When these rounded iclusions come into contact with the non-rounded inclusions their limits are well defined — I mean that there are no transitions in their contact regions.

Each rounded inclusion has been found (in the cases examined) to be a single crystal, but the non-rounded inclusions have a quartz-porphyritic composition.

The groundmass of the quartz-porphyry is very fine-grained, is composed of orthoclase and quartz and, at least in part, has a graphic texture; the biggest porphyritic quartz crystals have a diameter of about 1 mm., but they are generally somewhat smaller.

Titanite crystals with sectional dimensions of $(0{,}40 \times 0{,}20)$ mm.^{2} are observed, and likewise small crystals of zircon. The zircon crystals are zonally built.

There is uralite in accumulations and distributed in the groundmass in small crystals. The quartz-porphyry inclusions are connected with the uralitic dike-rock by means of transition-forms.

At the contact with the country-rock the dike-rock becomes very fine-grained and contains scattered quartz crystals, which are somewhat larger than the groundmass crystals, but their quantity and dimensions are not such as to give to the rock a porphyritic texture. The quartz crystals in question have a diameter of 0,10 mm.

As a rule the contact is irregular. This is because the dike magma has intruded, separating portions of the country-rock and penetrating into it in many fissures.

There are cases in which parts and isolated minerals of the country-rock are almost entirely included in the dike-magma, being connected with the former only by a narrow strip of rock. For instance, there is a quartz crystal almost surrounded by the dike-rock and only united by an orthoclase tongue to the country-rock. The quartz crystal is about 1,20 mm. in diameter and is impregnated by the dike-magma in a zone of 0,04 mm. in depth from the crystal faces inward. Over the crystal faces there is an accumulation of magnetite. In a broad zone at the contact the rock is somewhat spotted, as a consequence of an accumulation of minerals which are a little larger than the rest.

The granite of the inclusion is not much metamorphosed.

The metamorphism is shown by a richness in hornblende, some changes in the texture and a decoloration, but in general it closely resembles the granite of the country-rock.

The country-rock is of a deep brick-red; the granite of the inclusion has a pale red colour. The country-rock is almost free from dark-coloured minerals; the granite of the inclusion contains no small amount of green hornblende. The hornblende occurs in long, rod-like crystals, but also in beautiful, small euhedral crystals. It seems that the rock around the bigger orthoclase, perthite and quartz crystals has recrystallised. It is just the more fine-grained, micrographic implication around the larger crystals that has suffered the greatest changes.[1]

[1] See »Beskrifning till Blad 5 omfattande de Topografiska Kartbladen Lessebo, Kalmar etc.» af Herman Hedström och C. Widman, p. 78. Sveriges Geol. Und. Stockholm, 1906.

Instead of that implication we observe a microgranitic accumulation of orthoclase, quartz, plagioclase and hornblende, and it seems that at least the more fine-grained parts of the fragment have been fused.

The larger orthoclase crystals are devoid, not only of the primary micrographic texture surrounding them, in the building of which they took part with branching detachments from the periphery, but even of subhedrality. In the rock of the fragment the crystal faces have disappeared. The microgranitic ground-mass has won its place at the expense of the feldspars, as a consequence of the re-fusion of their outer regions, and in this manner there is not a single crystal showing a crystal face. The outer parts of the feldpar crystals have been fused together with the quartz, and have crystallised again as a microgranitic ground-mass. Here and there, however, are relics of the original micrographic texture that surrounded the big orthoclase and quartz crystals.

The hornblende (and even euhedral crystals of this mineral) are always observed in the microgranitic groundmass.

Naturally the metamorphic effects are less violent in the central than in the outer parts of the fragment. It is from the latter parts that the minor fragments in the neighbourhood of the big one have been detached. It seems that the irregular quartz-porphyritic inclusions show a more primary appearance than the rounded perthitic inclusions. The last-named probably show a more advanced stage of contact-metamorphism.

The reason why these rounded inclusions have crystallised in this way may be that the power of assimilation of the dike-magma was diminished, as a consequence of a lowering of the temperature, and then these rounded inclusions, though melted, remained distinct.

In any case, according to my field and laboratory observations, one thing is quite clear: that this kind of porphyritic rock is due to the fusing effect of the dike-magma upon a fragment detached from the country-rock.

I believe that, if some petrographer should see a single specimen of the dike rock with those rounded inclusions, but without the less metamorphosed, irregular quartz-porphyritic fragments, he would find it difficult to suggest the real circumstances of its genesis.

H. BÄCKSTRÖM[1] has described analogous phenomena.

Uralite-diabases of Torsgropen and Åskäret.

On the east coast of S. Ulfön, at about 700 m. to the south of the northern cape of the island, there is a place called by the fishermen »Torsgropen». At this place there are two dikes of dark-coloured rock cutting the granite.

[1] Über Fremde Gesteinseinschlüsse in einigen Skandinavischen Diabasen. — Meddelanden från Stockholms Högskola, N:o 108. — 1890. Stockholm.

One of them is about twelve meters in width and crosses the granite in the direction S 60° E mg. The dike-rock is very like that at Blåberget.

The primary composition has been principally *plagioclase* and *augite; quartz, orthoclase* and *magnetite* occur in lesser amounts.

The augite is now very altered; it is only in the central parts of a very limited number of crystals that one can observe this mineral. The greater part of it has been transformed into uralite.

The plagioclases are also very altered, but not as much as those from Blåberget, and it is also impossible to find crystals fresh enough for determination. I believe, however, that they were originally labradorites and acid bytownites, as in all the other dikes of this kind.

Quartz and orthoclase occur, generally in graphic implication, and form a kind of groundmass for the other minerals.

The crystallinity, granularity and texture are about the same as in the rock at Blåberget.

The smaller dike, which has a breadth of 0,80 m., is built of a rock unlike the above-mentioned and is very decomposed and fine-grained.

The plagioclases are indeterminable because they are too much altered.

Uralite is not observed, but, besides the ordinary decomposition-products of the feldspars, there is a widespread micaceous mineral, perhaps biotite, which may have originated from the hornblende.

The principal minerals are *plagioclase* and *magnetite,* possibly in the same proportions, and *quartz; orthoclase* I have not observed, but the rock is so decomposed that it is difficult to establish with certainty whether it exists or not.

The quartz occurs as isolated grains, but sometimes in accumulations of several crystals.

The most remarkable feature of this rock is, however, the great proportion of magnetite. It may be that this magnetite, at least in part, is of secondary origin.

At the contacts with the country-rock there is a thick accumulation of magnetite.

The dike-magma has penetrated between the minerals of the country-rock at the contact, including them; and at several centimeters from the contact it is possible to perceive its influence.

The red pigment of the orthoclase has disappeared completely from some crystals, though not from others; but it may be said that, in a zone of about two centimeters in width, the orthoclases are almost entirely decolorised. The accumulation of magnetite is sometimes greater around the included quartz crystals. Surrounding those crystals there is a corona comprised of a closely packed accumulation of magnetite grains, and around this a zone of rock poorer in magnetite than the rest of the rock-mass.

On the south-eastern coast of Askäret there is a dike of very altered

rock of a greenish-black colour. It is a «uralite-diabase». The dike has a width of about 1,70 m.

On the north-western coast of the same islet there are two dikes of the breadth of 0,90 m. and 0,30 m. respectively. They are also very altered uralite rocks. I have not observed either quartz or orthoclase in the dike-rocks of Åskäret.

As a rule the basic dikes cutting the granite are very altered; on the contrary, those which cross the diabase are, in most cases, well-preserved rocks.

Some general remarks on the above-described basalt and diabase dikes.

All these dikes younger than the Post-Jotnian diabase have probably originated from the same magma. This magma seems to have been of nearly the same composition as that of the Post-Jotnian diabase. There has been some differentiation, so that some of them are richer in iron and others show a great proportion of olivine or feldspar, just in the same way as in the Post-Jotnian diabase, though in the latter case the differentiation has been of much greater signification.

My field-studies have shown that all the anomalies are due to assimilation, alteration or both together.

It is very probable that the magma of these quartziferous uralite-rocks was originally of the same constitution as that which crystallised as olivine-basalts or olivine-diabases.

The quartz and orthoclase of these rocks would thus be assimilated from the granitic country-rock. That this is very probable is shown by the above-named occurrence at Blåberget.

Another circumstance that may be taken into consideration is that none of the dikes that cross the Post-Jotnian diabase are quartziferous, and that those of any size which cross the granite are rich in orthoclase and quartz.

The narrow dike (80 cm.) of Torsgropen (S. Ulfön), described above, may be considered as a ramification from the big dike.

Salic dikes.

General remarks.

In the Ulfö-diabase of the island itself, as well as in the varieties of this rock occurring in the Nordingrå region, are found veins and dikes[1] of a group of rocks which I consider to be closely connected with the aplites and pegmatites.

They are rocks showing grayish-white, gray, and reddish colours. Some of them are very rich in quartz, containing above 70 % of SiO_2, but others are devoid of quartz, and the proportion of SiO_2 declines to about 50 per cent.

Although the proportions of silica are variable, the rocks show some constant features in their constitution and their relations to the diabase, which remove any doubts that could exist as to their consanguinity.

All them are rich in feldspar — always albite. The proportion of this mineral in the rocks generally amounts to between 50 % and 70 %. Consequently, there is some analogy in composition with the albitites, and they may be considered as cognate to the latter.

They generally appear in sinuous and short, but well-defined, dikes; there occur however cases in which they pass into the country-rock; now and again these dikes may be long and straight, but their width is never great, generally being less than 40 cm.

Their granularity is variable, ranging from very fine-grained to medium-grained. There occur, however, very coarse-grained varieties, which may be considered to be kinds of pegmatites.

HOLMQUIST[2] describes a dike-rock from Gubben (an islet about 3 km. south of Rödö), which I believe belongs to the same group of rocks as the dike-rocks mentioned above. The rocks which HOLMQUIST observed on Gubben, cutting the diabase, (which is of the same type as the Ulfö-diabase) are — according to his description — narrow dikes, not more than 1 to 2 cm. in width. They are reddish and gray, fine-grained rocks, consisting almost entirely of *albite* and *quartz* in graphic implication.

[1] LUNDBOHM and HÖGBOM have observed such dikes, and HÖGBOM interpreted them as granitic secretions from the diabase.

[2] Om Rödöområdets Rapakivi och Gångbergarter. Sveriges Geol. Unders. Ser. C. N:o 181, 1899, p. 83.

Some *chlorite* and *calcite* are observed, and *titanite* is rather common. According to the analysis published by HOLMQUIST, the composition of one of these rocks was: $SiO_2 = 77{,}32$, $TiO_2 = 0{,}34$; $Al_2O_3 = 11{,}62$, $Fe_2O_3 = 1{,}57$; $FeO = 0{,}69$; $Mn = 0{,}10$; $CaO = 0{,}62$; $MgO = 0{,}80$; $K_2O = 0{,}99$; $Na_2O = 5{,}81$; $H_2O = 0{,}65$. HOLMQUIST points out that the rocks occurring on Gubben are analogous to some rocks described by HOWITT from Gippsland, in south-eastern Australia. HOLMQUIST considers that, for the present, the described dike-rock may be designated by the term *albite-pegmatite*.

In the following pages I shall describe an acid variety with a relatively large proportion of quartz, a basic variety quite free from quartz, and an intermediate variety.

Micropegmatitic dike from the southern region of Svartbergsviken.[1]

In the southern region of Svartbergsviken the coast is relatively steep, and quite near the shore occur several sinuous dikes of a grayish rock. The analysis of one of these dike-rocks is given in Table XIV. It consists of *albite, quartz,* and *pyroxene,* as essential primary constituents, and of *titanite, magnetite, calcite,* and *apatite,* as accessory minerals. As secondary product occurs a mineral which seems to be *muscovite* or *damourite*.

Albite. — When I observed what a great amount of CaO the analysis of this rock showed I hesitated about the determinations of the feldspar, and I revised my observations, but still I came to the conclusion that it must be an albite, because its refraction was nearly always below that of Canada balsam and the extinction angles on (010) were about 20°. The most usual twinnings in this feldspar are according to albite and pericline. The latter twinning is sometimes so well developed that in some sections — as for instance on (100) — the albite has the same appearance as microcline. The albite is very much altered to muscovite. It occurs in independent and relatively large anhedral crystals, and implicated with quartz and pyroxene. The sections of albite attain dimensions of 21 mm^2, but their areas are generally below that figure.

The *quartz* occurs in graphic implication with albite. The largest sections do not attain areas of above 2 $mm.^2$

Pyroxene. — This mineral occurs in subhedral and anhedral crystals, in part implicated with albite, and its sections attain areas of 2 $mm.^2$, but they are generally below 1 mm^2. The pyroxene is altered to a greenish-brown, fibrous mineral. The colour of the pyroxene is somewhat greenish, and I think it is a variety of the augite that occurs in the diabase; the greenish colour seems to be caused by alteration.

Titanite occurs in subhedral and anhedral crystals, with areas which sometimes attain 0,06 mm^2.

[1] Similar to this dike is the one mentioned on p. 23.

TABLE XIV.

Placerose (Micropegmatitic dike). Immediately south of Svartbergsviken (N. Ulfön). (Analyst, N. SAHLBOM).

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	0,20	—	—
H_2O (above 105°) . .	0,49	—	—
SiO_2	70,75	1,1792	75,12
TiO_2	0,17	0,0021	0,13
Al_2O_3	12,01	0,1177	7,50
Fe_2O_3	0,62	0,0039	—
FeO	0,94	0,0131	1,33
MnO	0,08	0,0011	0,07
CaO	6,13	0,1095	6,98
MgO	0,56	0,0140	0,89
K_2O	0,79	0,0084	0,53
Na_2O	7,20	0,1161	7,40
P_2O_5	0,10	0,0007	0,05
S	traces	—	—
CO_2	0,40	0,0091	—
BaO	traces	—	—
	100,44		

Quantitative Classification.

Formula	Mol.	Wt.		Norm			
SiO_2	33,03	× 60	= Quartz	= 19,82	Q	19,82	Sal 81,76
$K_2O . Al_2O_3 . 6 SiO_2$	0,84	× 556	= Orthoclase	= 4,67	F	61,94	
$Na_2O . Al_2O_3 . 6 SiO_2$	10,93	× 524	= Albite	= 57,27			
$Na_2O . Fe_2O_3 . 4 SiO_2$	0,39	× 462	= Acmite	= 1,80			Fem 17,98
$CaO . SiO_2$	2,61	× 116					
$MgO . SiO_2$	1,40	× 100	= Diopside	= 6,02	P	16,53	
$FeO . SiO_2$	1,21	× 132					
$Na_2O . SiO_2$	0,29	× 122	= Sodium metasilicate	= 0,35			
$CaO . SiO_2$	7,20	× 116	= Wollastonite	= 8,35			
$FeO . TiO_2$	0,21	× 152	= Ilmenite	= 0,32	T	0,32	
$3 CaO . P_2O_5$	0,07	× 310	= Apatite	= 0,22	A	1,13	
$CaO . CO_2$	0,91	× 100	= Calcite	= 0,91			

Class II	Order 4	Rang 3	Subrang 5
$\frac{Sal}{Fem} = \frac{81,76}{17,98} < \frac{7}{1} > \frac{5}{3}$;	$\frac{Q}{F} = \frac{19,82}{61,94} < \frac{3}{5} > \frac{1}{7}$;	$\frac{K_2O + Na_2O}{CaO} = \frac{12,45}{10,95} < \frac{5}{3} > \frac{3}{5}$;	$\frac{K_2O}{Na_2O} = \frac{0,84}{11,61} < \frac{1}{7}$
Dosalane	Austrare	Tonalase	Placerose

Osann's Classification.

s = 75,30	n = 9,33	
A = 7,93	a = 9,22	k = 1,33
C = 0,00	c = 0,00	
F = 9,27	f = 10,78	

Magnetite occurs in a few small grains, included in albite and pyroxene.

Apatite appears in small amount, but in crystals which sometimes attain a length of about 2 mm.

Calcite is observed in small quantities.

Muscovite. This mineral generally occurs in fan-shaped aggregations of very minute flakes. Sometimes it appears that the alteration of the albite has been more pronounced along the contacts with the quartz grains implicated with it. The quartz grains then appear surrounded by muscovite.

The rock is millimeter-grained and the predominant fabric is graphic. There occurs graphic implication between quartz and albite, and between this mineral and pyroxene.

The sequence of crystallisation has been: apatite, magnetite, titanite, pyroxene, pyroxene and albite, albite and quartz.

The analysis of this rock (Table XIV) shows a very great amount of CaO. This appears surprising, because the minerals in this rock which contain calcium are: pyroxene, titanite, and calcite, but their proportions seem to be too small to satisfy so great an amount of CaO. The relatively great amount of Na_2O which characterises this rock was to be expected as a consequence of the proportions in which the albite occurs. This is the only rock among those analysed in which the total amount of the alkalies is greater than that of the alumina.

Among the dikes of the southern region of Svartbergsviken there are some quite devoid of pyroxene, with much less quartz than the above-described, and containing much calcite and garnet as secondary constituents. Garnet occurs in nearly euhedral crystals of about 1 mm. in diameter. Some of them contain much titanite. The sections of this mineral attain areas of about 1 mm.^{2}. Some of the dikes consist exclusively of albite, as primary constituent, and some garnet and calcite as secondary minerals; they are consequently very near the albitites in composition. Thus, close together in the southern region of Svartbergsviken, occur narrow dikes of grayish rocks, 10 to 20 cm. broad; the rocks are of different compositions, but they show a common quality: that their most essential constituent is albite. Some of them are devoid of ferromagnesian minerals, and, moreover, do not contain quartz — they are albitites. These rocks are connected by means of transition-forms with others rich in quartz and albite, and with others containing pyroxene.

TABLE XV.

Salic dike at Vattenviken, N. Ulfön. (Analyst, N. SAHLBOM.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	1,14	—	—
H_2O (above 105°) . .	3,16	—	—
SiO_2	60,19	1,0032	66,66
TiO_2	0,50	0,0062	0,41
Al_2O_3	14,47	0,1419	9,43
Fe_2O_3	2,53	0,0158	—
FeO	0,78	0,0108	2,82
MnO	0,06	0,0008	0,05
CaO	3,80	0,0679	4,51
MgO	4,45	0,1112	7,39
K_2O	0,88	0,0094	0,63
Na_2O	7,53	0,1215	8,07
BaO	traces	—	—
P_2O_5	0,07	0,0005	0,03
S	traces	—	—
CO_2	0,38	0,0086	—
	99,94		

Quantitative Classification.

Formula	Mol.	Wt.		Norm.				
SiO_2	294 ×	60	= Quartz	= 1,764	Q	1,764	Sal	73,714
$K_2O . Al_2O_3 . 6 SiO_2$	94 ×	556	= Orthoclase	= 5,226	F	71,950		
$Na_2O . AlO_3 . 6 SiO_2$	1215 ×	524	= Albite	= 63,666				
$CaO . Al_2O_3 . 2 SiO_2$	110 ×	278	= Anorthite	= 3,058				
$CaO . SiO_2$	552 ×	116	= Diopside	= 11,923	P	17,523	Fem	21,537
$MgO . SiO_2$	552 ×	100						
$MgO . SiO_2$	560 ×	100	= Magnesium Metasilicate	= 5,600				
$FeO . Fe_2O_3$	54 ×	232	= Magnetite	= 1,253	M	3,859		
Fe_2O_3	104 ×	160	= Hematite	= 1,651				
$FeO . TiO_2$	62 ×	152	= Ilmenite	= 0,942				
$3 CaO . P_2O_5$	5 ×	310	= Apatite	= 0,155	A	0,155		

Class II	Order 5	Rang 2	Subrang 5
$\frac{Sal}{Fem} = \frac{73,7}{21,5} < \frac{7}{1} > \frac{5}{3}$;	$\frac{F}{Q} = \frac{71,9}{1,76} > \frac{7}{1}$;	$\frac{K_2O + Na_2O}{CaO} = \frac{13,09}{6,79} < \frac{7}{1} > \frac{5}{3}$;	$\frac{K_2O}{Na_2O} = \frac{0,94}{12,15} < \frac{1}{7}$
Dosalane	Germanare	Monzonase	

Osann's Classification.

s = 67,10 n = 9,28
A = 8,70 a = 7,41 k = 0,99
C = 0,73 c = 0,62
F = 14,04 f = 11,97

A Dike at Vattenviken.[1]

A fine-grained, somewhat porphyritic rock cuts the diabase at Vattenviken. It is of a pale reddish colour, caused by the colouring of the feldspars. In the rock appear *albite*, as the most important mineral, and *quartz*. As accessory constituents occur *magnetite, ilmenite, apatite, titanite, calcite,* and *hornblende*. The secondary minerals are: *garnet, chabazite, epidote, muscovite,* and *chlorite*.

The *albite* occurs in anhedral crystals of sectional areas ranging between 1 and 3 mm.[2] It is somewhat red-pigmented and turbid.

Quartz appears in small amounts; in one slice I found about 40 rounded grains of about 0,30 mm in diameter.

Magnetite, ilmenite, apatite, and *calcite* occur in very small amounts; and in one slice I observed anhedral and altered crystals of greenish *hornblende*.

Garnet occurs in rounded grains of about 0,20 mm. in diameter. It presents brownish-yellow shades and appears to be *grossularite*. It is not quite isotropic. The birefringence is variable in the same crystal, and its maximum appears to be about 0,0016.

Chabazite. — There occurs a white mineral with a very distinct cleavage. Its refringence is low — about the same as that of Canada balsam — and birefringence weak, never attaining 0,003. I could not get a distinct interference figure. Presumably it is chabazite. It appears filling small cavities.

Muscovite and *chlorite* appear as decomposition-products, the former of the feldspar and the latter of the ferro-magnesian minerals.

Epidote. — This mineral is characterised by its high refringence and strong birefringence, which latter varies for the same crystal. The pleochroism is very intense and varies from bright red to lemon-yellow. All the properties of this mineral are characteristic of piedmontite. The crystals are very irregular, and the sections show dimensions of about 0,20 mm.[2] This kind of epidote is, moreover, very common in accumulations, filling cracks in the diabase.

This rock is millimeter-grained and the texture is the «panidiomorphkörnige» texture of ROSENBUSCH. The albite, being the most common mineral, determines the texture of the rock, and, the albite crystals being of the same order of magnitude, the rock may be called equigranular. Chemically this rock is characterised by the great amounts of Na_2O. See Table XV.

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[1] Vattenviken is a little cove which lies about 1 km. to the south-east of Sandviken (N. Ulfön).

TABLE XVI.

Beerbachose. Inmediately south of Norrsand (N. Ulfön).
(Analyst, N. SAHLBOM.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°) . .	0,40	—	—
H_2O (above 105°) . .	1,07	—	—
SiO_2	52,55	0,8758	58,43
TiO_2	1,23	0,0154	0,89
Al_2O_3	15,39	0,1509	10,07
Fe_2O_3	5,61	0,0351	—
FeO	9,10	0,1264	13,12
MnO	0,22	0,0031	0,21
CaO	5,46	0 0975	6,50
BaO	traces	—	—
MgO	2,19	0,0547	3,65
K_2O	1,19	0,0126	0,84
Na_2O	5,80	0,0935	6,24
P_2O_5	0,12	0,0008	0,05
S	0,10	0,0031	—
	100,36		

Quantitative Classification.

Formula	Mol.	Wt.		Norm				
$K_2O . Al_2O_3 . 6 SiO_2$	126	× 556	= Orthoclase	= 7,006	F	68,454	Sal	68,454
$Na_2O . Al_2O_3 . 6 SiO_2$	935	× 524	= Albite	= 48,994				
$CaO . Al_2O_3 . 2 SiO_2$	448	× 278	= Anorthite	= 12,454				
$CaO . SiO_2$	500	× 116						
$MgO . SiO_2$	207	× 100	= Diopside	= 11,738	P	13,758	Fem	30,648
$FeO . SiO_2$	293	× 132						
$MgO . SiO_2$	70	× 100	= Hypersthene	= 2,020				
$FeO . SiO_2$	100	× 132						
$2 MgO . SiO_2$	270	× 70	= Olivine	= 5,786	O	5,786		
$2 FeO . SiO_2$	382	× 102						
$FeO . Fe_2O_3$	351	× 232	= Magnetite	= 8,143	H	M 10,484		
$FeO . TiO_2$	154	× 152	= Ilmenite	= 2,341	T			
$3 CaO . P_2O_5$	8	× 310	= Apatite	= 0,248	A	0,620		
FeS_2	31	× 120	= Pyrite	= 0,372				

Class II — Order 5 — Rang 3 — Subrang 5

$$\frac{Sal}{Fem} = \frac{68,45}{30,65} < \frac{7}{1} > \frac{5}{3}\ (\text{Dosalane});\quad \frac{F}{Q} = \frac{68,45}{0} > \frac{7}{1}\ (\text{Germanare});\quad \frac{K_2O + Na_2O}{CaO} = \frac{10,60}{9,75} < \frac{5}{3} > \frac{3}{5}\ (\text{Andase});\quad \frac{K_2O}{Na_2O} = \frac{1,26}{9,35} < \frac{1}{7}\ (\text{Beerbachose})$$

Osann's Classification.

s = 59,37	n = 8,81	
A = 7,08	a = 4,63	k = 0,86
C = 2,99	c = 1,96	
F = 20,49	f = 13,41	

Dike-rocks in the region immediately south of Norrsand.

In the region south of Norrsand occur several narrow salic dikes of a somewhat reddish colour. The analysis given in Table XVI represents one of the most basic rocks observed in these dikes, which are very sinuous. Their geological appearance is very like that of those in the southern region of Svartbergsviken. One of these dike-rocks consists of *albite,* some *quartz,* and small amounts of *orthoclase, hornblende, magnetite, apatite.* As secondary mineral occurs *epidote.*

Other dike-rocks, not represented by the analysis of table XVI, are quite free of quartz and contain relatively much augite. The other minerals are those occurring in the varieties described above; consequently: *albite, orthoclase, augite, hornblende, magnetite, apatite, titanite;* and the secondary minerals, *epidote, calcite, hornblende, muscovite.*

The *augite* appears to be about the same variety as that of the diabase of the main body, and its sections show an area of about 9 mm.^{2} It is partially transformed into hornblende, and in those regions of the crystal where the mineral is quite fresh it shows the same reddish-brown colour as the augite of the Ulfö-diabase.

The *albite* occurs in relatively large crystals, whose sections attain an area of about 20 mm.^{2} Generally it is turbid, and some muscovite flakes appear included in it here and there. The forms of the crystals are quite irregular. The albite appears implicated graphically with the augite in the peripherical regions of the crystals of the latter mineral. Furthermore, albite, augite, and magnetite occur in graphic implication.

Orthoclase has not been determined with certainty, and, if it occurs, it is in very small amounts.

The *hornblende* in this rock, as in many others described above, is, at least in part, of secondary origin. The augite passes into a fibrous amphibole, and this into a compact hornblende. The absorption formula is Z = dark green > Y = dark brownish-green > X = brownish-yellow. The hornblende appears implicated with albite. There occur accumulations of relatively small crystals of this mineral, and even of hornblende and magnetite. Sometimes hornblende and magnetite appear together in implication.

The *magnetite* occurs in considerable amount and generally in large grains, or accumulations; seldom in small grains. The crystals are always anhedral, and in some of these accumalations the minerals appears intercalated with *titanite.*

Apatite. — It seems to me that the analysis of the rock shows too small a proportion of apatite, or it may be that the slices happened to be cut through a region of the rock where apatite occurred in relatively large amounts. The mineral appears in small euhedral, and in larger subhedral, crystals. The small crystals have a length of about 0,10 mm. (in the dir-

ection of the c-axis); the larger ones attain 2 mm. in length. Apatite occurs included in all the other minerals.

Besides the accessory minerals mentioned there, are found sporadic occurrences of pyrrhotite. *Epidote* and *calcite* occur in small quantities.

This rock is millimeter-grained and nearly equigranular, and the graphic fabric plays a not insignificant rôle.

The order of crystallisation appears to have been: apatite, magnetite, magnetite and augite, magnetite augite and albite, albite.

In its composition, its texture, and its geological relations the rock is a connecting link between the above-mentioned micro-pegmatitic and aplitic varieties and the coarser rocks of pegmatitic type, which will be described in the following lines.

Värnsingite.

On the eastern coast of Västra Värnsingen (West Värnsingen) occur several dikes of a coarse-grained, whitish rock, which, because of its uncommon mineralogical composition and texture, I call Värnsingite, after the island where I found it.

The dikes are short and generally narrow — not more than some 20 or 30 cm. in width. In the locality in question they appear at the shore and are continued beneath the water, but inland they grow narrower, and some of them disappear at some meters from the water-line. The rock is rather salic in the centre of the dikes, but the femic minerals increase in amount in the contact zones.

White feldspars, greenish pyroxene, and brownish accumulations of titanite can be distinguished macroscopically. Here and there occur radial aggregations of a dark green epidote. Magnetite is also distinguishable here and there.

The rock consists of *albite, pyroxene, titanite, magnetite,* and *apatite,* as primary constituents, and *epidote, prehnite,* and *muscovite* as secondary.

The *albite* is the commonest mineral and appears in greater amount than all the other minerals put together. It occurs in large crystals, whose sections attain an area of over 100 mm.^{2} In the contact zones the same kind of crystals appear with much greater dimensions; there are sections of 2 cm.^{2} This mineral is rather altered, especially in the contact regions of the dike, but that it is albite is shown by the fact that its refraction is lower than that of Canada balsam; in sections parallel to (010) the extinction angle is about 20°, and the bisectrix Z is nearly perpendicular to this face. The albite occurs implicated with magnetite and pyroxene, not in a graphic implication like that between orthoclase, or perthite, and quartz, but less regular, and in a manner that shows the symultaneous crystallisation of these minerals.

Pyroxene. This mineral generally shows varying shades of green.

There occur all the transition-colours between these greens and a brownish tinge. It seems to me that the greenish variations are the consequence of alteration, and that the original colour is brownish. This pyroxene is an augite, and I am inclined to think it is the same augite as that occurring in the Ulfö-diabase, with the difference in colour pointed out above. The crystals are large, their sections attaining dimensions of about 30 mm.^{2} For the most part the pyroxene occurs implicated with albite. Sometimes when in small crystals it appears showing subhedral outlines.

Magnetite. Except in rare cases this mineral occurs in rather large crystals of anhedral and subhedral shapes, whose sections attain dimensions of 4 mm.^{2} It often appears in company with titanite. The biotite, which in the Ulfö-diabase and its varieties appears surrounding magnetite, is absent from this rock. As has been mentioned above, it occurs implicated with albite and augite.

The *titanite* occurs in rather large crystals showing sections of 10 mm.^{2} The shapes of the crystals are generally anhedral. It includes crystals of apatite and magnetite. The pleochroism is not intense, but distinct in brown and yellow shades. The absorption formula is Z = brown > Y brownish-yellow > X = pale brownish-yellow. The colour is variable, even in the same crystal. The dispersion is very strong and the axial angle small. Perhaps the variations of colour in the same crystals are due to alteration.

Apatite occurs in euhedral and subhedral crystals, the smaller of which are generally well-faced, but not the larger. These latter attain a length of 5 mm. and a diameter of 0,30 mm. The mineral occurs in rather large amounts, in spite of the large proportions of feldspars. Compare the observations made on p. 59 with reference to the occurrences of apatite in the anorthosites.

As has been mentioned above, *epidote, prehnite, chlorite, amphibole,* and *muscovite* occur as secondary minerals. *Epidote* and *prehnite* occur in fan-shaped crystals, the latter sometimes showing a very fine twinning lamination like that of microline, and exhibiting anomal interference colours — deep azure blue passing into a leather-brown shade. The dispersion is very distinct, $\rho > \upsilon$, and the angle of the optic axes is not large — about the same as for augite. I have not observed orthoclase in this rock.

The order of crystallisation has been: apatite, magnetite, magnetite and titanite and augite, magnetite and augite and albite, albite.

The Värnsingite is a rock which, in its composition, its field-relations, and its texture, may be considered to be a kind of pegmatite — a diabase-pegmatite.

This rock is connected with the other salic dike-rocks which present a micropegmatitic and aplitic appearance. However, the last-named generally (though not always) contain too much pyroxene to be considered proper aplites, but among them there are typical aplites (albitites).

TABLE XVII.

Beerbachose (Värnsingite). Västra Värnsingen. (Analyst, N. Sahlbom.)

	Per cent	Mol.	Mol. per cent
H_2O (below 105°)	0,15	—	—
H_2O (above 105°)	0,80	—	—
SiO_2	56,33	0,9388	60,85
TiO_2	1,76	0,0220	1,43
Al_2O_3	16,25	0,1593	10,37
Fe_2O_3	1,22	0,0076	—
FeO	3,46	0,0481	4,03
MnO	0,13	0,0018	0,12
CaO	6,92	0,1236	8,01
MgO	4,89	0,1222	7,92
K_2O	0,39	0,0041	0,27
Na_2O	6,26	0,1010	6,55
P_2O_5	0,96	0,0068	0,44
S	traces	—	—
BaO	0,00	—	—
	99,52		

Quantitative Classification.

Formula	Mol. WT.		Norm.			
SiO_2	105 × 60	= Quartz	= 0,630	Q	0,630	Sal. 70,90
$K_2O . Al_2O_3 . 6 SiO_2$	41 × 556	= Orthoclase	= 2,280	F	70,272	
$Na_2O . Al_2O_3 . 6 SiO_2$	1010 × 524	= Albite	= 52,924			
$CaO . Al_2O_3 . 2 SiO_2$	542 × 278	= Anorthite	= 15,068			
$CaO . SiO_2$	468 × 116					
$MgO . SiO_2$	332 × 100	= Diopside	= 10,544	P+O	20,549	Fem. 27,76
$(Fe,Mn)O . SiO_2$	136 × 132					
$MgO . SiO_2$	821 × 100					
$(Fe,Mn)O . SiO_2$	136 × 132	= Hypersthene	= 10,005			
$FeO . Fe_2O_3$	76 × 232	= Magnetite	= 1,763	M	5,107	
$FeO . TiO_2$	220 × 152	= Ilmenite	= 3,344			
$3 CaO . P_2O_5$	68 × 310	= Apatite	= 2,108	A	2,108	

$$\frac{\text{Sal}}{\text{Fem}} = \frac{70{,}90}{27{,}76} < \frac{7}{1} > \frac{5}{3}; \quad \text{Class II, Dosalane}$$

$$\frac{\text{F}}{\text{Q}} = \frac{70{,}27}{0{,}63} > \frac{7}{1}; \quad \text{Order 5, Germanare}$$

$$\frac{K_2O+Na_2O}{CaO} = \frac{1051}{1236} < \frac{5}{3} > \frac{3}{5}; \quad \text{Rang 3, Andase}$$

$$\frac{K_2O}{Na_2O} = \frac{41}{1010} < \frac{1}{7}; \quad \text{Subrang 5, Beerbachose}$$

Osann's Classification.

s = 62,72	n = 9,60	
A = 6,82	a = 5,07	k = 0,97
C = 3,55	c = 2,64	
F = 16,53	f = 12,29	

Albitites have been described by H. W. TURNER,[1] and by L. DUPARC and F. PEARCE.[2] I have not myself read the publications of DUPARC and PEARCE, and the reference is quoted from »Physiographie der Mineralien und Gesteine» by ROSENBUSCH.

The age-relations of the salic dike-rocks with the basalt and diabase described above are not quite clear. The sinuous salic dikes are generally medium-grained and never show chilled margins, but on the contrary the straight dikes — at least those which I studied — are fine-grained at the contacts. These circumstances may be interpreted as meaning that the solidification of the sinuous dikes was nearly contemporaneous with the solidification of the diabase; they may have solidified when the country-rock was still at a high temperature. The other, larger and straighter dikes, with chilled margins are probably of younger age, and solidified when the diabase was cool.

The basalt and doleritic dikes always show chilled contacts, and they are always glassy, at least in the marginal region. For this reason I am inclined to think that these rocks are younger than the sinuous salic dikes, (I have never observed a basalt dike cutting through a sineous salic dike, but neither have I observed the contrary phenomenon). There are cases in which a straight salic dike occurs together with a basaltic dike, forming a composite dike. The two magmas have been successively intruded along the same fissure; the younger rock (the basalt) being flanked by the older (albititic) rock.

Consequently, the conclusion I come to with regard to the age-relations of the dike-rocks mentioned above is that the sinuous, salic dikes are nearly contemporaneous with the diabase; that the straight salic dikes with chilled margins are somewhat younger; and that the basaltic and doleritic dikes are the youngest rocks of the district. I cannot decide if there is more than one generation of basaltic and doleritic dikes, but I am inclined to think that there is not. It is my purpose to study this question further, and I shall publish my results in a subsequent paper.

[1] Further Contributions to the Geology of the Sierra Nevada; U. S. Geological Survey, Seventeenth Annual Report, 1895—96, Part I. (Director's Report and other Papers), p. 521. — The Granitic rocks of the Sierra Nevada; The Journal of Geol. vol. 7, 1899, p. 141.

[2] Sur les roches éruptives du Tilai-Karnen (Oural). C. R. 1901. CXXXIII, 596. — Recherches géologiques et pétro graphiques zur l'Oural du Nord dans la Rastenkaya et Kizelowskaya-Datcha (Gouv. de Perm). Génève 1902.

Explanation of the Plates.

PLATE I.

View taken from Körning (Vågsfjärden, Nordingrå), with the camera facing south-east. In the background, to the right, appears the table-mountain Ringkalleberget. The steep diabase-cliff is seen at its northern extremity. The contact between the diabase and the sandstone is just at the point where the steep of the mountain is seen rather abruptly to change to a more gentle slope. The horizontal stretch which appears immediately to the left is the table-land south of Barntjärn and east of Sörleviken. In the background in the middle of the plate appears a hill of anorthosite; the hill to the left of this, and the wooded heights, and the islands in the middle distance, consist of gabbro.

PLATE II.

Skrubban (an island south-west of Trysundaön). The view is taken from the NE. The whole island consists of diabase, except for a small region on the north-western coast, where sandstone appears in an escarpment below the steep diabase wall.

PLATE III.

The granite-arkose at Trysundaön. The hammer is 75,5 cm. in length.

PLATE IV.

Fig. 1. At the water-line appears the sandstone in undisturbed layers, with a dip of 5° degrees to the south-east. Inclined upward from the left can be traced layers of sandstone lifted by the diabase magma, which has thrust itself in between the sandstone strata.

Fig. 2 is from a locality some meters to the south of that of Fig. 1, and represents the same phenomenon, but the sandstone strata are tilted in a contrary direction. The dark patch near the water-line on the left-hand side is diabase, and the region on the right-hand side where the trees are thickest is also diabase.

PLATE V.

Fig. 1. Banded diabase in the region south of Norrsand.

Fig. 2. Eruptive breccia in the peninsula east of Salsåker (Ullångerfjärden, Nordingrå).

PLATE VI.

Fig. 1. Peridotite, Västra Värnsingen. The magnificatio is about 17,5 diameters. The black region in the bottom right-hand corner of figure is magnetite, and the crystals included in it are of olivine. The white regions are plagioclase crystals. The subhedral, somewhat rounded crystals, are of olivine, and the mineral in the right half of the figure showing distinct parallel cleavage is augite. This augite includes olivine crystals.

Fig. 2. Ulfö-granite (from Norrtaskberget quarry), showing the porphyritic quartz crystals with the same orientation as the quartz of the groundmass. Furthermore, there occur sacciform inclusions in the quartz. Magnification 16,6 diameters.

PLATE VII.

Fig. 1. Ulfö-diabase from the quarry west of Hamnberget. In the central parts is observed a large augite crystal, and, imbedded in it, plagioclase and olivine crystals. In the right-hand half of the figure near the centre, below the large plagioclase and in contact with it, appears an olivine crystal. In the left-hand, top corner appears an apatite crystal, and in the left-hand, bottom corner appear magnetite, olivine, and biotite crystals. Magnification about 17 diameters.

Fig. 2. The same rock and the same magnification. In the central region appears magnetite surrounded by biotite. Included in the magnetite appear two olivine grains. Augite is to be observed in the lower part.

PLATE VIII.

Fig. 1. Titaniferous iron-ore. The black mineral is magnetite, and, as may be seen, is the first mineral to have separated. The white anhedral mineral is plagioclase. The rounded crystal near the centre is olivine. Magnification 17,5 diameters.

Fig. 2. Titaniferous iron-ore. Besides magnetite, olivine, and plagioclase, occurs augite in anhedral grains, appearing with a darker shade than the olivine, and including this mineral. Magnification 17,5 diameters.

PLATE IX.

Fig. 1. A region in an anorthositic rock on Västra Värnsingen, relatively rich in augite. Magnification about 25 diameters.

Fig. 2. A large anhedral magnetite crystal including plagioclases, in an anorthosite on Västra Värnsingen. Magnification about 19 diameters.

PLATE X.

Fig. 1. Basalt from the northern region of Norrsand. Centre of the dike. Between crossed nicols. The figure shows plagioclase and olivine phenocrysts in accumulations. The white rounded crystal in the right-hand half of the figure is olivine. The other crystals are easily recognisable. Magnification about 17 diameters.

Fig. 2. Showing the rounded and unrounded inclusions in the uralite-diabase of Blåberget (N. Ulfön). Near the central part, and in the left-hand, bottom corner, appear the quartz-porphyritic unrounded inclusions. Natural size.

PLATE XI.

Contact between granite and leptite. The upper part is metamorphosed leptite. Natural size.

PLATE XII.

Fig. 1. (Fishing-harbour, Trysundaön). The hill is Kapellsberget, seen from the SSW. The steepest part of its northern slope is diabase; the gentle slope below is sandstone and arkose.

Fig. 2. The northern part of Fäbodsjön (S. Ulfön). Note the steep eastern shore.

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Errata.

Page	5, l. 14	from top,	*for* diabase-forming table-mountains appear	*read*	diabase — forming table-mountains — appear.
»	12, » 6	» bottom,	*for* appropiate	*read*	appropriate.
»	15, » 20	» »	» quarzitic	»	quartzitic
»	34, » 3	» top,	» axis	»	axes
»	37, » 22	» »	» axis	»	axes
»	42, » 17	» bottom,	» leucoxen	»	leucoxene
»	51, » 10	» top,	» afanitic	»	aphanitic
	53, » 10	» bottom,	» olivinegrains	»	olivine grains
»	67, » 12	» top omit the word: to			
»	69, » 13	» bottom,	*for* exeptionally	*read*	exceptionally
»	71, » 10	» »	» dipersion	»	dispersion
»	80, last line,		» been not	»	not been
»	81, l. 11	from bottom omit the word: to			
»	93, » 3	» top,	*for* charply	*read*	sharply
»	96, » 10	» bottom,	» quantities- of course-within	*read*	quantities — of course, within
»	99, » 1	» top,	» escarpement	*read*	escarpment
»	101, bottom line,		» appears	»	appear
»	120, l 8	from bottom,	» varietes	»	varieties
»	127, » 20	» »	» transitions	»	transition
»	128, » 15	» »	» implaced	»	implicated
»	151, » 20	» top,	» emply	»	imply
»	156, » 3	» bottom,	» iclusions	»	inclusions

Note to the map.

Vaviken is the narrow bay cutting into the anorthosite to the north-east of Ulfvik.

Fig. 1.

Fig. 2.

Fig. 1.

Fig. 2.

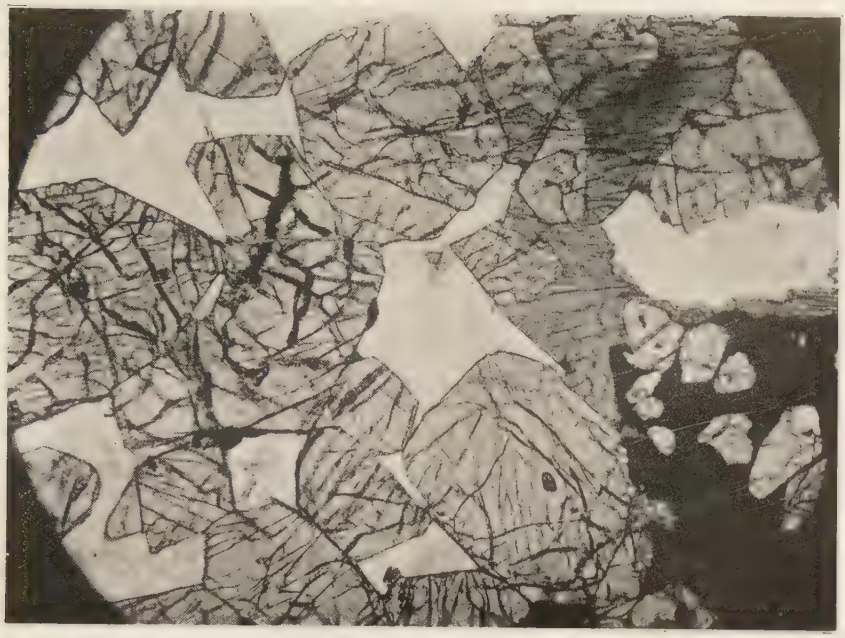

Fig. 1.

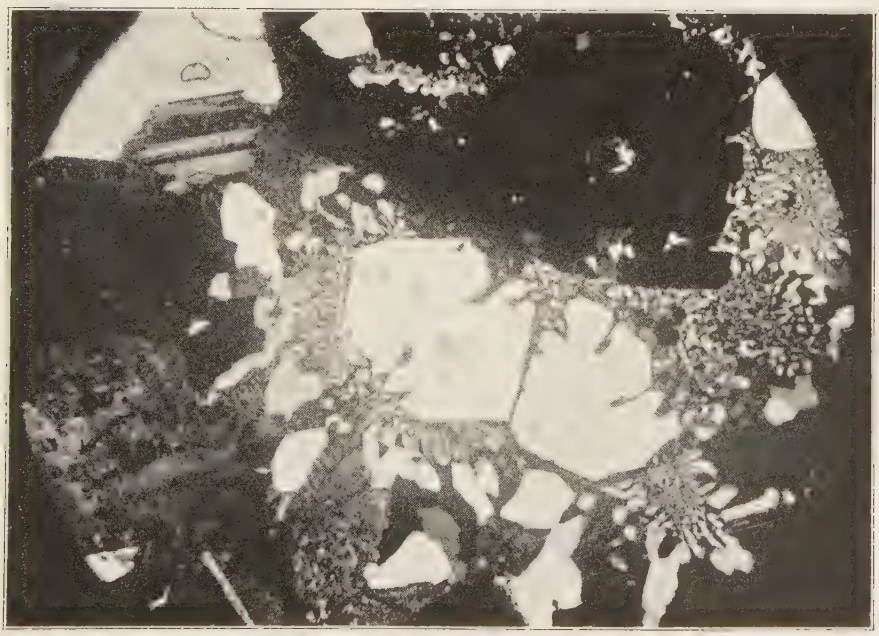

Fig. 2.

Fig. 1.

Fig. 2.

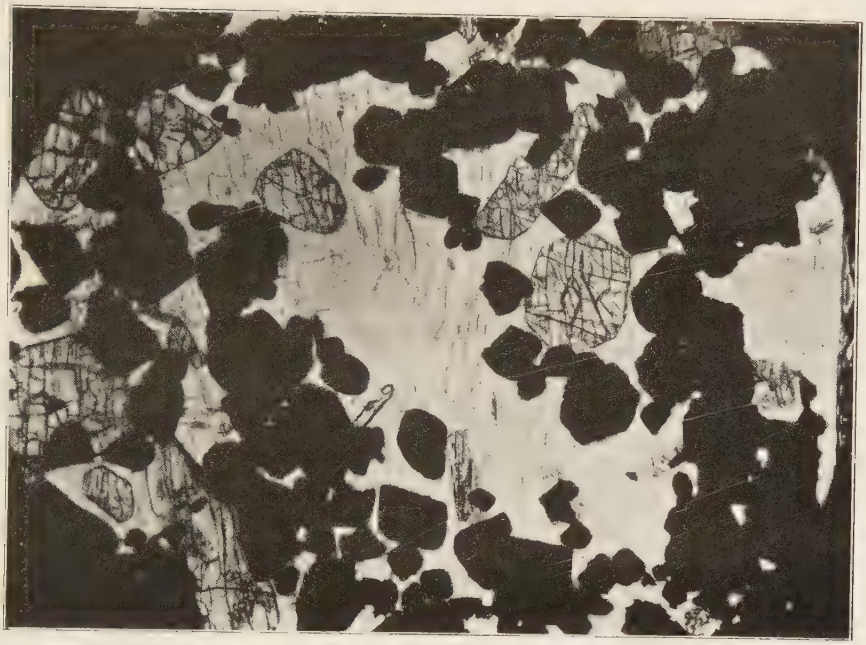

Fig. 1.

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Fig. 1.

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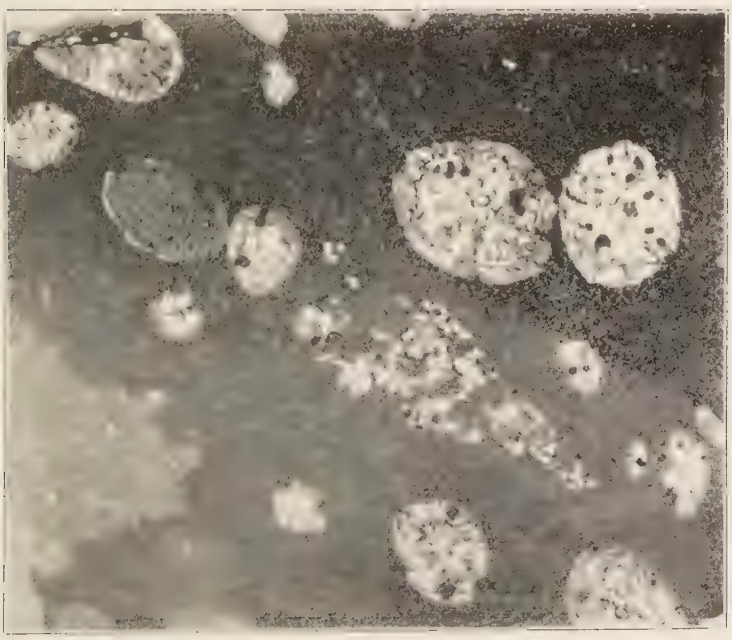
Fig. 1.



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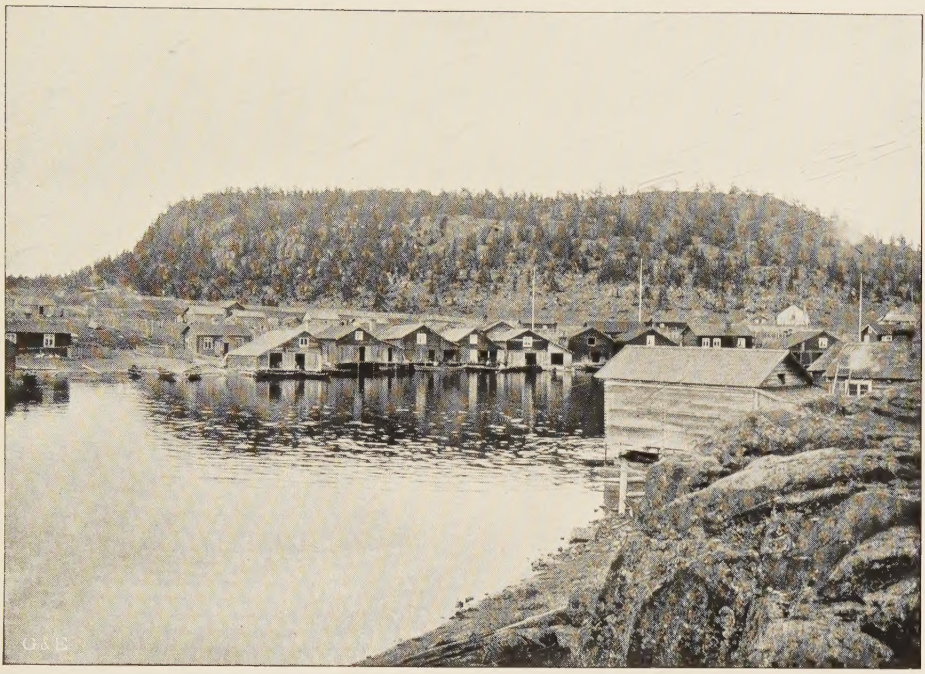

Fig. 1.

Fig. 2.